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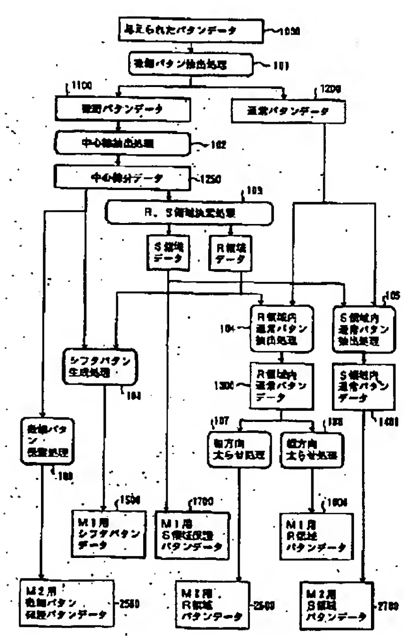
(54)【発明の名称】　ホトマスク及びマスクパタンデータ処理方法

(57)【要約】　(修正有)

【目的】多重転写法におけるマスクパターンの容易な自動生成を可能とし、さらに複数マスク間における位置合わせずれの影響を減少させるマスクパターンを提供する。

【構成】位相シフトパタン１５００を含むマスクM１を用いた露光と、それによる不要なパタンを消去する露光を含む複数回露光のパタン形成において、露光領域を位相シフタが必要な微細パタン１１００を有する領域とそうでない領域３に分割し１０３、１枚のマスクはシフタを設け、領域１では、微細パタンに対応したエッジを持つマスクシフタパタンと他のパタン１６００に対応したパタンを持ち、領域３は遮蔽するマスクパタンとし、シフタなしの別の１枚のマスクは、領域３に存在するパタン２６００を形成する通常のパタンと、シフタ形成領域のパタンで不要なパタンを除去するためのパタンをもたせるように自動生成する。さらに、１枚のマスクではマスクパタンを一つの軸方向に太らせ、他のマスクでは直交する方向にマスクパタンを太らせる。



【特許請求の範囲】

【請求項1】形成しようとする微細パタンの両側を透過する光の位相差をおおよそπとするように位相をシフトさせるパタンを含むマスクを用いた露光と、それにより生じる不要なパタンを消去するための露光を含む複数回の露光により、一つの層のパタンを形成するパタン形成において、

前記微細パタンを形成するため位相差のある光が透過するために必要となる第1の領域を設定する第1の工程と、形成する全パタンあるいは前記微細パタンを除く全パタンを前記第1の領域の内と外とに分離する第2の工程を含むことを特徴とするマスクパタンデータ処理方法。

【請求項2】前記第1の領域を決定するにあたり、両側を透過する光の位相差をおおよそπとして形成される微細パタンの長さが、最終的に形成される細線の長さよりも、少なくとも複数枚のマスク間の相互の重ね合わせで生ずる重ね誤差に相等する距離だけ、微細パタンの軸方向の両側それぞれに長くなるように前記第1の領域の境界を設定することを特徴とする請求項1記載のマスクパタンデータ処理方法。

【請求項3】形成しようとする微細パタンの両側を透過する光の位相差をおおよそπとするように位相をシフトさせるパタンを含むマスクを用いた露光と、それにより生じる不要なパタンを消去するための露光を含む複数回の露光により、一つの層のパタンを形成するホトマスクにおいて、位相差のある光を用いて形成しなければならないパタンを微細パタン、微細パタン以外の従来用いられてきたマスク上の遮光体を転写して形成するパタンを通常パタンと呼ぶこととし、また微細パタンの細い線が伸びている長手方向を軸方向、軸方向と直角の向きを幅方向と表現することとしたとき、前記微細パタンを形成するため位相差のある光が透過するために必要となる第1の領域内のパタンに対し、微細パタンを形成するマスクでは、前記第1の領域内の通常パタンは軸方向には最終的に前記複数回の露光により形成されるパタンの長さで、かつ幅方向には最終的に前記複数回の露光により形成されるパタンの幅より所定の長さだけ広げた寸法を有し、他のマスクでは、前記第1の領域内の通常パタンは軸方向には最終的に前記複数回の露光により形成されるパタンの長さより所定の長さだけ広げた寸法を、かつ幅方向には最終的に前記複数回の露光により形成されるパタンの幅の寸法を有することを特徴とするホトマスク。

【請求項4】形成しようとする微細パタンの両側を透過する光の位相差をおおよそπとするように位相をシフトさせるパタンを含むマスクを用いた露光と、それにより生じる不要なパタンを消去するための露光を含む複数回の露光により、一つの層のパタンを形成するホトマスクにおいて、

両側を透過する光の位相差をおおよそπとして形成される微細パタンの長さが、最終的に前記複数回の露光により形成される細線の長さよりも、所定の距離だけ、微細パタンの軸方向の両側それぞれに長くなるように前記第1の領域の境界が設定されていることを特徴とするホトマスク。

【発明の詳細な説明】

【0001】

【産業上の利用分野】本発明は、ＬＳＩ等の微細パタンを投影レンズを用いてウエハ（基板）上に形成するときのマスクパタン作成方法、マスクならびにパタン形成方法に関するものである。

【0002】

【従来の技術】従来よりＬＳＩ等の微細パタンを形成するための投影露光技術では、高い解像度が要求されている。そのため投影露光装置の投影レンズでは、光の波長から決まる理論限界に近い解像度を有するに至っている。さらに近年においては、より微細なパタンを転写するための方法として位相シフト法の検討が進んでいる。位相シフト法では、投影レンズの物面に置かれるマスク上の光透過部の一部に、透過光におおよそπの位相差が生じるような透明膜を付加することで、解像度を高めることが可能となる。この位相シフト法はいくつかの手法に分類することができるが、孤立した微細な線パタンを形成する方法として、位相シフト膜の端部で生じるおおよそπの位相差を利用したパタン形成法がある。この方法を図１７を用いて説明する。図１７（ａ）は、位相シフトマスクの断面の一部を示しており、60はマスクを照明する光、61はマスク基板、1500は位相シフト膜で、図中には位相シフト膜1500の存在する部分と存在しない部分との境界辺（シフタエッヂ）が存在している。このマスクを通過した光の複素振幅分布は図１７（ｂ）のようになり、対応する光強度分布は図１７（ｃ）のようになる。ここで、図１７（ａ）、（ｂ）、（ｃ）は横軸が対応しているものとする。これらの図は、エッヂ部で位相がπ変化するため、対応する部分の光強度が０になることを示している。このように位相シフト膜の端辺は非常に細い遮光部を形成し、例えば高圧水銀灯のｇ線（波長が４３６ｎｍ）を用いる場合、焦点深度まで考慮すると、通常のクロム等でできた遮光体パタンを転写すると０．５μｍ幅程度が限界だが、このシフタエッヂを用いると０．２μｍ幅のパタンまで形成できる。この線幅を限界解像線幅と呼ぶこととする。このようにシフタエッヂの利用は、微細なパタン形成への適用が期待されている。

【０００３】このシフタエッヂの利用にあたり、２つの点を補足説明しておく。１つはパタン密度の限界についてである。シフタエッヂを用いると微細幅の遮光部が形成できるが、そのためには遮光部の両側に位相差のある光が透過していることが必要である。このことは、２本の微細幅の遮光部を近づけて形成するには、その間隔に

限界があることを示している。図17（d）は、0．2μm幅の遮光部を間隔pで連続して形成する場合を示したものだが、遮光部の間隔pは1μm近くが必要となる。

【0004】他の1点は、遮光部の線幅の制御についてである。最も微細な線幅を得るには位相差πのシフタエッヂを用いれば良く、そのとき線幅0．2μmが可能となる。しかし実際のLSIパタンの形成では、通常の遮光体を転写して得られる最小線幅、例えば0．5μmよりも細く、先のシフタエッヂで得られる寸法、0．2μmよりも太い線の形成が要求される場合がある。図18（a）、（b）にこれらの間の線幅の形成方法を示す。（a）は、位相シフトマスクの断面を示している。シフタエッヂ部にクロム等でできた遮光体を挿入し、その遮光体の線幅を調整することで、限界解像線幅以上のパタン幅を実現できる。（b）は、位相シフトマスクの平面構造を示している。位相シフト膜のエッヂ部に、細かい折り返しを設けることにより限界解像線幅以上のパタンを実現できる。このように、通常の遮光体を転写して得られる線幅以下でも限界解像線幅以上のパタンであれば、シフタのエッヂを利用して形成可能となる。図18（a）、（b）も含めてこのようなパタン形成法をここではシフタエッヂ法と呼ぶこととする。

【0005】シフタエッヂ法を用いたパタン形成の最大の問題点は、全てのエッヂで微細なパタンが形成されてしまうことにある。図19はその説明図で、（a）に形成したい微細パタン1100を、（b）に（a）で示した微細パタンをシフタエッヂ法で形成するための位相シフトパタン1500を含む位相シフトマスクを、（c）に（b）で示したマスクを用いて形成されるパタン15を示す。シフタのエッヂ部で不要なパタンが形成されるのが判る。この不要パタンを生成させない方法として、①多段位相シフト膜を利用した手法と②複数枚マスクを用いた多重転写法とが提案されている。

【0006】多段位相シフト膜を利用した手法とは、位相差の異なる複数の位相シフト膜を用い、微細パタンが必要な部分はその両側の位相差をπとするものの、パタン形成が不要な部分はその両側の位相差を例えば60度としてパタンを形成させない手法である。この方法は、1枚の位相シフトマスクで所望のパタンが形成可能だが、多段の位相シフト膜を作る必要があり、マスク製作が難しい致命的欠点を有する。

【0007】図20（a）、（b）、（c）は、2枚のマスクを用いた多重転写法を説明した図で、図19の（a）を形成すべきパタンとしている。図20（a）は図19（b）と同じ位相シフト膜付きのマスク1、（b）は遮光体のみで構成されるマスク2を示している。（c）はこれら2枚のマスクをパタン形成のために重ねた状態で示してある。2枚のマスクを用いて露光した後現像すると、2枚のマスク両方で遮光された部分の

みが、最終的な遮光部としてパタン形成される。（c）の破線で示したパタンがこれに相当する。即ち、マスク1の位相差がπとなる境界辺で微細なパタンを形成しておき、マスク2で、不要な部分は露光して除去する。この多重転写法は、使用する位相シフト膜として、透過する光の位相差でπ相当となる1種だけで良く、マスク製作が容易な利点を有している。

【0008】

【発明が解決しようとする課題】従来、この多重転写法を用いた不要パタンの除去法として、個々のパタンに対して人手でシフタや遮光部を配置することは可能だったが、複雑にパタンが混在する場合に、それらのパタンを自動的に発生・配置させる方法は提案されていなかった。また、実際のパタン形成プロセスにおいて、異なるマスクを用いた2回の露光により一つの層のパタンを形成しようとする場合、その2回の露光の間での位置合わせの誤差発生はさけられない。図21は2回の露光において相対的な位置ずれが生じた際にパタンが受ける変形の一例を示している。図21（a）は形成しようとするパタン8、（b）はそのため用いる1枚目のマスク（M1）で、遮光体部13と位相シフトパタン1500とから構成され、（c）はM1を用いた露光によって潜像として得られたパタン10に、2枚目のマスク（M2）を位置ずれ無しに重ねた様子を示している。M2の光透過部14に対応する領域に存在する潜像は除去されるので、（a）に示した目的のパタンが形成できる。これに対して（d）はM2がM1に対し上に位置ずれを生じながら転写された場合を示している。M1で形成される不要パタンを除去するためのM2上の光透過部が、形成すべきパタンの潜像に重なって、微細なパタンの両側の通常パタン部は一部を失う変形を受け、微細パタン部にもくびれを生じさせている。

【0009】本発明は以上の点に鑑みてなされたものであり、その目的は位相シフト法を用いたLSI等の回路パタン形成にあたり、複数枚のマスクを用いた一層のパタン形成において、使用する複数枚のマスク間での位置合わせ誤差の影響を少なくするようならしめたマスクパタン作成方法およびそのマスクの提供であり、さらには、適用するLSI等に一部のパタン上の制約を加えるもののシフタのパタンを含むマスクパタンの自動生成法を提供することにある。

【0010】

【課題を解決するための手段】はじめに、ここで用いる用語を解説しておく。形成するパタンのうち、シフタエッジを用いて形成する幅の狭いパタンを<u>微細パタン</u>1100、従来通りマスク上に存在する遮光体を転写して形成するパタンを<u>通常パタン</u>1200と呼ぶ。形成するパタン、すなわち与えられたパタン1000は、必ず微細パタン1100あるいは通常パタン1200に分類され、例えば幅が0．5μm以上のパタンは通常パタン1200、0．5μm未満は

微細パタン1100として分類することが可能である。また、微細パタン1100の長さは、その幅に対して充分に、例えば4倍以上、長いとし、その長く伸びている方向を軸方向、軸方向に対して直角の方向を幅方向と呼ぶことにする。また、シフタエッジ法を用いて微細パタンを形成するには、その微細パタンの両側に位相がおおよそπ離れた光が透過する領域が必要で、その領域を位相指定領域R 1あるいはR領域 1と呼ぶ。パタンを形成しようとしている領域 4、例えばチップ領域で、R領域以外の部分をS領域 3と呼ぶ。パタン形成領域全体 4は、R領域 1とS領域 3とから成り、R領域 1とS領域 3は重なることがない。また、R領域とS領域の境界をRS境界 2と呼ぶ。図22、図23、図24にこれらを図示した。微細パタン1100は本来幅のあるパタンだが、図22では、図が煩雑となるのを避けるため一本の線分として記述した。

【0011】まず、本発明を概略的に説明する。多重転写法を用いるが、ここでは2枚のマスクを用いた2回の露光に限定し、1枚目（M1）は位相シフト膜（シフタ）のあるマスク、2枚目（M2）はシフタのないマスクとする。すなわち、1回目の露光でシフタエッジを用いた微細パタンを形成し、2回目の露光では形成された微細パタンのうち、必要な部分は保護し、また不要な部分は露光して除去する。

【0012】ここで説明等を容易にするため、次の3つの前提条件を導入する。

（前提条件1）微細パタン1100は全てX軸に平行とする。

（前提条件2）お互いに近傍に隣接して存在する微細パタン1100の中心線の間隔は、一定値pに一致するか、あるいはpの整数倍に一致する。

【0013】（前提条件3）微細パタン1100の線幅は1種類のみとし、その線幅dは、幅pのシフタが間隔pで並んでいるときにできる遮光部で形成されるパタンの幅に等しいとする。

図22のパタンは、これらの条件を満足している。さて、本発明の目的の一つは、与えられたパタンからM1用のシフタパタンと遮光体パタン、およびM2用の遮光体パタンを自動的に生成することである。そのために与えられたパタン1000から、位相指定領域R 1を算出し、通常パタン1200をR領域内に存在するパタン1300と、R領域外すなわちS領域に存在するパタン1400とに分離する。

【0014】図22を与えられたパタン1000としたとき、位相指定領域R 1としては、例えば図23、図24に示した領域が考えられる。この図では省略したが、どちらにおいても位相差πを生じさせる位相シフト膜が、図26のように周期的に存在している。図23、図24とも、一番上の微細パタンの上部と一番下の微細パタンの下部に、それぞれ微細パタンの中心線から、距離p離れた領域までをR領域 1としている。

【0015】図23は、微細パタン1100形成に必要とされる光透過部分のみをR領域 1としているため、R領域 1は微細パタン1100に応じた複雑な形状の領域となっている。それに対し、図24は、R領域 1を長方形領域とし、そのX方向の境界は微細パタン1100形成で必要とされる境界のなかから、最も広範囲な領域をおおうことができるように決める。ここでは、R領域 1として、その算出が容易な長方形領域を採用する。R領域を求める具体的手順については実施例で述べる。

【0016】R領域 1が求まれば、与えられたパタン1000を、R領域内に存在するパタン1300と、S領域に存在するパタン1400とに分離することは容易である。その結果、1枚目のマスクM1は、図26のような平面構造とし、R領域 1内の微細パタンを含むパタン（図26では微細パタンのみ）を形成し、S領域 3は遮光して保護する。図26で、点が散りばめてある領域はシフタ1500であり、そのエッジで微細パタン1100が形成される。左下がりの斜線で覆った領域1700が遮光部である。一方、2枚目のマスクM2では、図27のようにS領域 3の通常パタンを形成し、R領域 1は遮光して保護するとともに、M1で形成された不要な微細パタンを露光して除去する。右下がりの斜線で覆った領域が遮光部である。

【0017】このようにR領域 1の導入は、微細パタンを形成する領域とそれ以外の領域を分離し、それぞれの領域内のパタンを独立にパタン形成することを可能ならしめ、シフタを含むそれぞれの領域内のパタンを与えられたパタン1100から自動発生させることを可能としている。図26、図27は、そのままではまだ欠点を有しているものの、これから述べるように改良した手法においても、R領域 1の導入がパタンの自動発生に大きな役割を果たしている。

【0018】本発明のもう一つの目的は、複数のマスク間に相対的な位置ずれがあった場合でも、できるだけ忠実にパタンを転写できるようにすることである。図26、図27に示したM1とM2を誤差無しに転写できれば、目的とする与えられたパタン1100が形成できるが、実際には、M1とM2とには相対的な位置ずれが存在する。すなわち、M1のRS境界 2とM2のRS境界 2とは重ならない。その結果、例えば、M2がM1に対して右上に位置がずれて転写された場合を考えると、M2のR領域 1の上辺部と右辺部は、M1のS領域と重なり、M1でもM2でも遮光され、未露光となって不要パタンが形成される。このことは、RS境界 2近傍で露光すべき部分に対しては、M1とM2の両方から露光されなければならないことを示している。

【0019】図27のM2では、R領域 1の必要な微細パタンの潜像を保護するため、不要な潜像部分を除いて領域内全てを遮光部としたが、保護しなければならないのはR領域内のパタン部のみである。そこで、マスクの

位置ずれがあってもパタン部が露光されないように、合わせずれを見込んだ量だけR領域内のパタン部を少し大きくした領域のみを遮光部とし、他の部分は透過部とする。このようにすると、領域Rの境界でパタンが存在しない部分（例えば図２７のR領域の上辺部）については合わせの位置ずれが生じても、未露光パタンが生じることはなくなる。

【００２０】さらに、ＲＳ境界部　2にパタンが存在する場合について、マスクの合わせずれがあったときの対処法について本発明を説明する。まず、微細パタンの端部がＲＳ境界部 2にある場合について述べる。図２４の円で囲った部分51がこれに相当する。この部分を拡大し、Ｍ１で形成される潜像10と、Ｍ２で保護される部分12との重なりおよびその結果得られるパタン15について、マスクの合わせずれが無い場合を図２８（a）に、Ｍ２が左にずれた場合を（b）に示す。合わせずれの無い図２８（a）では、予定通りのパタンが形成されているが、合わせずれの有る（b）では、得られる微細パタン15の先端がふくらんでしまう。この現象を解決するため、R領域 1の左右端の決定に際し、図２５に示すように、微細パタンが存在する区間よりも、軸方向両側にそれぞれαだけ広げた領域をR領域 1とする。また、Ｍ１で形成した微細パタンに対してのＭ２での保護パタン2500は、微細パタン1100の幅方向には、合わせずれを考慮して太らせるものの、軸方向には太らせないこととする。このように処理を施した場合に得られる図形を、図２９に示す。図２９（a）は形成すべき微細パタン1100とＲＳ境界 2の位置関係を、（b）、（c）は合わせずれが無い場合と有る場合に、Ｍ１で形成される潜像10とＭ２で保護される部分12との重なりおよびその結果得られるパタン15を示している。合わせずれの有無にかかわらず、忠実なパタンが転写できている。微細パタン1100の形成において、領域R 1を軸方向両側にαずつ広げることで、マスクの合わせずれが生じた場合でも、パタンの変形が生じないこと、微細パタンのY方向の位置はＭ１により、X軸方向の位置はＭ２により決めることが可能となる。

【００２１】次に領域Rを軸方向にαだけ広げたことにより、通常パタン1200がＲＳ境界部に存在する図３０（a）の場合について述べる。まず、合わせずれに対して何も対処していない今までの場合にパタンがどのような変形を受けるかを述べる。図３０（b）、（c）は、それぞれＭ１、Ｍ２のパタンを示す。Ｍ２ではR領域内1の通常パタンに対し一様に太らせて大きくしてある。これは、既に述べたように、マスクの合わせずれがあってもＭ１で形成した潜像を保護するためである。合わせの誤差なく転写されれば、図３０（a）のパタンが得られるが、例えばＭ２が左下にずれて転写されると、図３０（d）のように、形成パタン15は、R領域1 内の太らせた部分がS領域3 に侵入してパタンに突起を生じさせ、隣接する他のパタンの妨げとなる。

【００２２】本発明では、このような問題を避けるため、R領域内の通常パタンに対し、Ｍ１では幅方向（y方向）にのみ片側δだけ太らせ、Ｍ２では軸方向（x方向）にのみ片側δだけ太らせる処理を施す。図３０（a）のパタンに対す本発明を適用したＭ１、Ｍ２のパタンを図３１（a）、（b）に示す。Ｍ１、Ｍ２が合わせ誤差無く転写された場合、Ｍ２が右上にずれた場合、Ｍ２が左下にずれた場合を、それぞれ図３１（c）、（d）、（e）に示す。いずれも形成されるパタン形状はくびれや突起を生じさせず、設計パタンをほぼ忠実に反映している。これは、R領域内の通常パタンをＭ１では上下方向に、Ｍ２では左右方向に分離して太らせたため、合わせずれが生じても、領域の内外に関係なく、領域内通常パタンの左右辺（図３０の例では右側の辺）のみがＭ１で規定され、残る辺はＭ２で規定されることによる。

【００２３】

【作用】形成しようとする微細パタンの両側を透過する光の位相差をおおよそπとするように位相をシフトさせるパタンを含むマスクを用いた露光と、それにより生じる不要なパタンを消去するための露光を含む複数回の露光により、一つの層のパタンを形成するパタン形成においては、複数のマスクで共通に露光が遮蔽された領域がパタンとして残る。露光領域を位相シフタが必要な微細パタン有する領域とそうでない領域に分割することにより、１枚はシフタを設け、微細パタンを有する領域では、微細パタンに対応したエッジを持つマスクシフタパタンと他のパタンに対応したマスクパタンを持ち、微細パタンを有しない領域は遮蔽するマスクパタンとし、別の１枚のマスクはシフタを設けずに、シフタを設けない領域に存在するパタンを形成する通常のマスクパタンと、シフタを形成する領域に属するパタンで不要なパタンを除去するためのマスクパタンをもたせるというように、２枚のマスクに於けるシフタパタンとマスクパタンを容易に自動生成できるようになる。さらに、形成されるパタンは２枚のマスクで共に遮蔽される部分であるので、１枚のマスクではマスクパタンを一つの軸方向に太らせ、この軸と直行する方向に、他のマスクではマスクパタンを太らせることにより、マスク間の位置ずれが形成するパタンに与える影響を著しく減少させ、位置合わせ余裕度を大きくできる。

【００２４】

【実施例】ＬＳＩで微細なパタン形成が要求されるゲート層に本発明を実施する場合をのべる。実施例の処理の流れを図１に、与えられた入力パタンデータと本発明を用いて作成したマスク製作用のパタンデータを図２から図６に示す。図２は、微細パタンを含む入力パタンデータ1000で、「課題を解決するための手段」で述べた三つの前提条件を満足していることとする。図３、図４は２

枚のマスクＭ１、Ｍ２で、これらを用いて図２のパタンを形成する。Ｍ１はシフタ付き、Ｍ２はシフタ無しである。既に述べたように、通常パタンはＲ領域とＳ領域とに分離してパタン発生させるので、Ｍ１のマスクを製作するには、シフタ用のパタンデータ1500、Ｒ領域パタンデータ1600、Ｓ領域保護パタンデータ1700の３種類パタンデータが必要となる。同様に、Ｍ２のマスクを製作するには、Ｍ１のシフタで作成した微細パタンを保護するためのパタンデータ2500、Ｒ領域パタンデータ2600、Ｓ領域パタンデータ2700の３種類パタンデータが必要となる。図３、図４にこれらのパタンを示す。

【００２５】図１は、入力パタンデータ1000から、Ｍ１とＭ２用それぞれ３種の計６種のパタンデータ1500、1600、1700、2500、2600、2700を作成する処理の流れを示している。角の丸い四角はデータ処理を表し、その入出力は普通の四角で示したパタンデータとなっている。データ処理は 101から 109まで九種類が必要で、以下にそれぞれの処理内容と具体的な実現方法を示す。なお、ここで述べる実現方法はあくまでも一手法であって、これに限定されるものではない。

【００２６】以下に述べるデータ処理は、２次元の図形データであるマスクデータを扱う。２次元図形データに対しての輪郭抽出、リサイズと呼ばれる一律幅の太らせや細らせ、チップ領域に対しての白黒反転処理、あるいは複数の入力データがあるときの積集合演算などは、ＬＳＩマスクパタンデータの設計規則チェック（ＤＲＣ、Design Rule Check ）あるいはマスクを電子ビームを用いて描画するたのデータ処理で、すでに一般的に処理が行われている。従って、ここでは一般的に行われている処理であれば、処理の具体的な手法は説明を省くこととする。具体的な手法については、例えば、『自動化が進むＬＳＩマスク・パターン・データの検査』、日経エレクトロニクス、1980.4.28.、pp90-107を参照されたい。

【００２７】微細パタン抽出処理 101

与えられたパタン1000を、微細パタン1100と通常パタン1200とに分離する。微細パタンの幅ｄが既知であれば、以下の処理で求められる。

(1)与えられたパタン1000を、距離 d/2細らせる。

(2)輪郭を抽出する。

(3)(2)の結果を、距離 d/2太らせる。得られた結果が通常パタン1200である。

(4)与えられたパタン1000から、通常パタン1200を減算すれば、得られた結果が幅ｄの微細パタン1100である。

【００２８】図２を与えられたパタン1000とし、図７に与えられたパタン1000とともに、距離 d/2細らせて、輪郭抽出した結果の図形1010-1から1010-4を、図８に図形1010-1から1010-4を距離 d/2太らせて得られた通常パタン1200-1から1200-4と、これを基に得られた微細パタン1100-1から1100-4を示す。普通、微細パタンの線幅は既知であるが、不明な場合には、微細パタンとして考えられる最大の大きさ、例えば0.49μｍをｄとして、上記の処理をまず実行する。得られた微細パタン1100は、幅0.49μｍ以下のパタン全てを含んでいる。次にｄを僅かに小さくして、同じ処理を実行する。この処理を、順次ｄを僅かに小さくしながら繰り返すと、いつか微細パタンが無くなり、零集合となる。その直前のｄが微細パタンの幅に一致している。

【００２９】中心線抽出処理 102

微細パタンの中心線分1250を求める処理である。前提より、微細パタンの線幅は一種類であり、微細パタン抽出処理 101より線幅は既知だから、処理は容易である。微細パタン1100-1から1100-3と、中心線分1250-1から1250-4の関係を図９に示す。

【００３０】Ｒ、Ｓ領域決定処理 103

微細パタンの中心線分データ1250を基に、Ｒ領域 1およびＳ領域 3を決める処理である。中心線分データは全てでｎ個あるとし、また、近接した中心線分データが並んでいる間隔ｐは既知とする。未知の場合でも、データを解析することで知ることができるからである。

(1)中心線分データ1250の幅方向に、両側に距離Ｌずつ太らせて、幅２Ｌの矩形とする。

(2)(1)で得られたｎ個の矩形をもとに輪郭抽出処理を施し、矩形同士が繋がって形成される多角形に番号づけし、多角形を構成する各矩形にその多角形番号を付与する。

(3)ｎ個の矩形データを多角形番号でソーティングし、同一多角形を形成する矩形を取り出し、その多角形領域を覆うことができる最小の矩形領域を求める。

(4)(3)で求めた矩形領域を軸方向両側にαずつ広げ、新たな矩形領域とする。この新たな矩形領域同士が互いに重なるか接する場合には、それらに同一の多角形番号を付与し、(3)へ戻る。

(5)(4)で得られた矩形領域の幅方向を両側Ｌずつ細らせ、その後ｐずつ太らせる。得られた領域がＲ領域 1である。

(6)パタン形成領域に対して(5)で得られたＲ領域 1を減算してＳ領域 3が求まる。

【００３１】おたがいに近傍に存在する中心線分を集めて、Ｒ領域を求める処理である。本実施例での処理の説明を図１０、図１１に示す。中心線分1250-1から1250-4それぞれを、幅２Ｌの矩形とすると全てつながり、一つの多角形となる。他に多角形が存在しないため、上記処理の(3)(4)(5)により、図１１のＲ領域 1が求まる。(1)の処理で、隣接する中心線分データの間隔が２Ｌ以下であれば、２つの矩形は繋がって一つの多角形とすることができる。従って、

$$2p < 2L < 3p$$

とすれば、図１０に示すように、隣接する中心線分データの間隔が２ｐまでなら一つのＲ領域となり、３ｐ離れていれば別のＲ領域と見なすことができる。

【0032】R領域内通常パタン抽出処理 104　及びS領域内通常パタン抽出処理 105

R領域内通常パタン抽出処理 104では、R領域決定処理 103で得られたR領域データと通常パタンデータの積集合演算により、R領域内通常パタンデータが容易に求められる。S領域内通常パタン抽出処理 105も同様である。図12に、R領域内通常パタン1300-1から1300-4、およびS領域内通常パタン1400-1から1400-2を示す。

【0033】幅方向太らせ処理 106

R領域内通常パタン1300を幅方向に、両側それぞれにδ太らせる。結果を図13に示す。R領域内通常パタン1300-1から1300-4が、M1用R領域パタン1600-1から1600-4となる。δは2枚のマスクの相対的な合わせ精度で決まる量で、例えば0．2μmという値が考えられる。

【0034】軸方向太らせ処理 107

R領域内通常パタン1300を軸方向に、R領域内においてδ太らせる。結果を図14に示す。R領域内通常パタン1300-1から1300-4が、M2用R領域パタン2600-1から2600-4となる。同図に、M2用S領域パタン2700-1、2700-2もあわせて示す。δは、幅方向太らせ処理 106と考え方が同じであり、同一の値とした。

【0035】シフタパタン生成処理 108

R領域データとそれに対応する中心線分データを入力して、シフタ用パタンを生成する。R領域毎に、中心線分データ1250を幅方向（例えば図15では、y方向に上から下へ）ソーティングしておけば、中心線分データ1250を順に取り出して、シフタの無い領域、有る領域と割り当てれば良い。図15が割り当てた結果である。

微細パタン保護処理 109

中心線分データ1250を、幅方向にε太らせて、M2用の微細パタン保護パタン2500を作成する。図16に実施例を示す。εは、幅方向太らせ処理 106で用いた、マスク間の合わせを考慮した値δと同一でも良いが、ゲート電極となる微細パタンを完全に遮光して寸法精度を高める意味で、ε＞δとし、例えば03．μmの値が用いられる。

【0036】以上述べてきた九種類の演算処理を実施することにより、M1、M2のパタンの自動発生が可能となる。M1は、図3に示すように、シフタパタン1500-1、1500-2、S領域の保護パタン1700、およびR領域通常パタン1600-1から1600-4を用いて構成される。M2は、図4に示すように、微細パタン保護パタン2500-1から2500-4、R領域パタン2600-1から2600-4、およびS領域パタン2700-1、2700-2を用いて構成される。

【0037】図5に、2枚のマスクが誤差無しに重なった場合を示す。光で露光した部分が現像により溶解するポジ形レジストを使用すると、M1で形成される潜像領域10とM2の遮光部で保護される領域12の積集合部分が未露光となって、パタンが形成される。図2のパタンが形成されていることが判る。図6は、M2がM1に対して、左下にずれて転写された場合である。微細パタンと通常パタンとの相対位置等がずれているものの、パタン形状に致命的な欠点はない。ゲートパタンでは、他の層、例えばコンタクトホール層との重ね精度が問題となるが、この点では、1枚のマスクを用いる普通の手法と本発明による手法とで有為な差は存在していない。

【0038】さて、スタンダードセル設計方式を用いたゲート層パタンを前提として、課題を解決するための手段で述べた3つの前提条件の制約について補足説明をしておく、微細パタンが全てX軸に平行となる前提条件1は、全てがY軸に平行であったとしてももちろんかまわないし、さらに言えば位相が指定されている第一の領域が複数ある場合には、それぞれの領域について、その領域に含まれる微細パタン全てがX軸あるいはY軸に平行であれば良い。

【0039】微細パタンの中心線部分の間隔がpないしpの整数倍という条件2は、スタンダードセル方式では満たされていると考えて良い。微細パタンの線幅に対しての第3の条件については、図18に説明したシフタエッチ法を適用すれば、線幅に対しての制約はなくなる。また線幅の種類に対しては、微細パタン抽出処理101,その微細パタン形成に必要な、例えばシフタエッチ部に要求される遮光体の幅の決定とそのパタン発生処理，およびM2での微細パタン保護処理109 におけるパタン幅が複数種類になることを考慮すれば、1種類に限定する必要はない。実際、CMOSのゲートパタンはP型MOSトランジスタとN型MOSトランジスタとでゲートパタンの幅が異なることが生じるが、以上のことから対応は容易である。

【0040】従って、本発明手法は、スタンダードセル設計方式を用いたゲート層パタンの形成に適用可能であり、さらには、微細パタンが等間隔に並んでいる等のパタン形成に、適用可能な可能性が高い。

【0041】

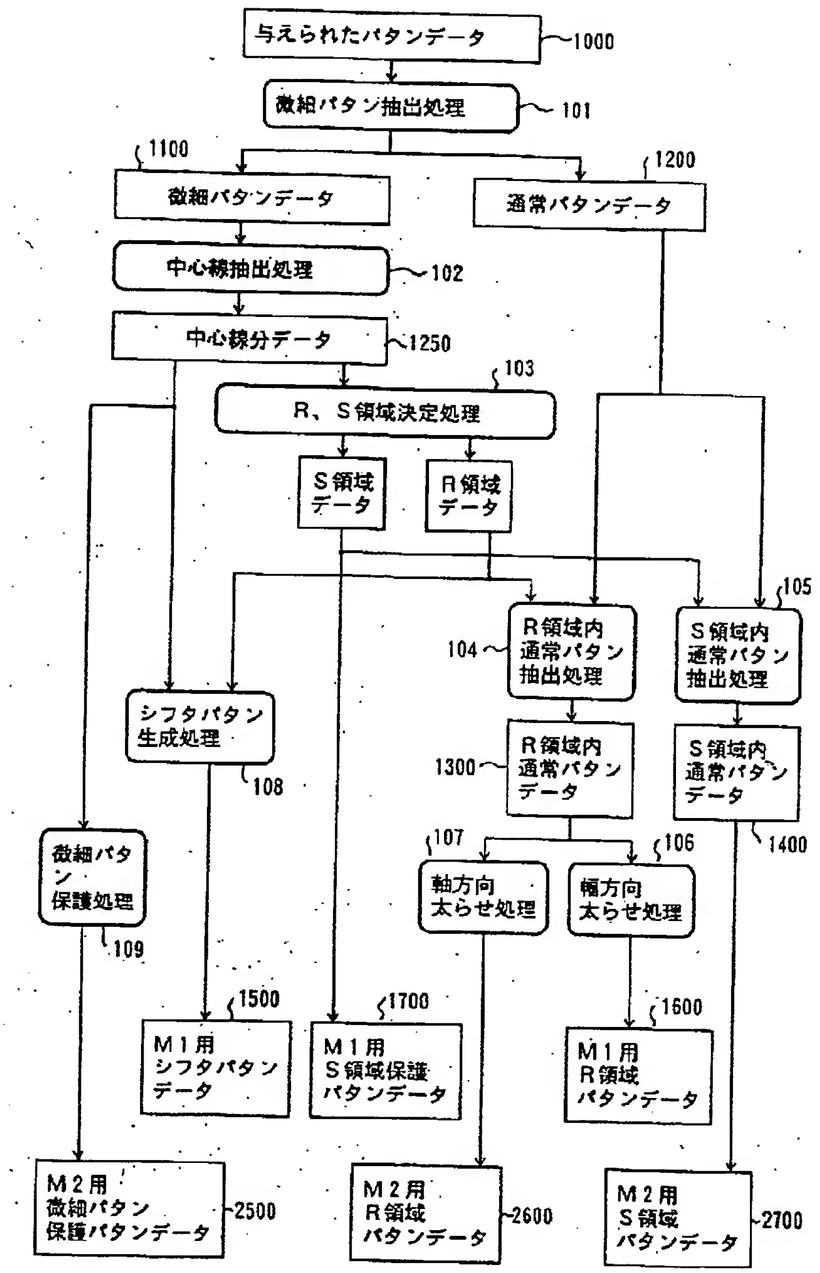
【発明の効果】本願発明は以上説明したように構成されているので、以下に記載されるような効果を奏する。

露光領域を位相シフタが必要な微細パタン有する領域とそうでない領域に分割することにより、微細パタンを形成する領域とそれ以外の領域を分離し、それぞれの領域内のパタンを独立にパタン形成することを可能ならしめ、シフタを含むそれぞれの領域内のパタンを与えられた形成すべきパタンから自動発生させることを可能としている。

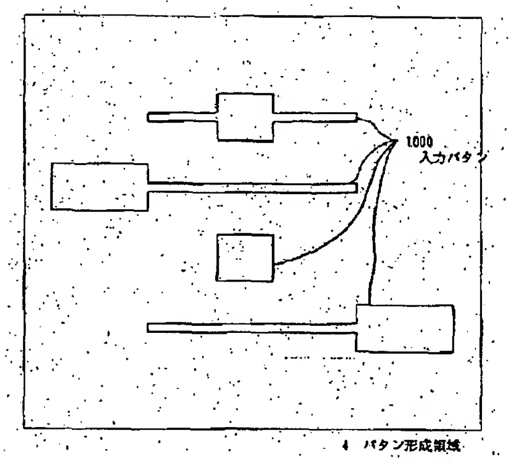
【0042】そして、位相シフタが必要な領域の通常パタンをマスクM1では上下方向に、マスクM2では左右方向に分離して太らせることにより、M2がM1に対して位置ずれして転写された場合でも形成されるパタン形状はくびれや突起を生じさせず、設計パタンをほぼ忠実に反映したパタンが形成できるというように位置ずれの影響を小さくできる。

【図面の簡単な説明】
【図1】与えられたマスクパタンから位相シフト膜のパタンを含む位相シフトマスク用のパタンを自動発生させる処理の流れ
【図2】形成すべきパタン。
【図3】本発明を実施したときの図2のパタンを形成するための1枚目のマスクの平坦配置図。
【図4】本発明を実施したときの図2のパタンを形成するための2枚目のマスクの平坦配置図。
【図5】図3と図4の2枚のマスクが位置ずれなく重なって転写したときのパタン説明
【図6】図4のマスクが図3のマスクに対し左下方向に位置ずれして転写したときのパタン説明。
【図7】微細パタン抽出処理101の説明。
【図8】微細パタン抽出処理101の説明。
【図9】微細パタンの中心線分抽出処理102説明。
【図10】R，S領域決定処理103の説明
【図11】R，S領域決定処理103の説明
【図12】R領域ないの画像パタン抽出処理104の説明とR領域ないの画像パタン抽出処理105の説明。
【図13】R領域ないの通常パタンに対して幅方向太らせ処理106の説明。
【図14】R領域ないの通常パタンに対して軸方向太らせ処理107の説明。
【図15】シフタパタン生々処理108の説明。
【図16】微細パタン保護処理の説明。
【図17】位相シフト膜のエッジを利用した位相シフト法の説明
（a）位相シフトマスクの断面図
（b）（a）のマスクを透過した光の複素振幅
（c）（a）のマスクを透過した光の強度分布
（d）位相シフト膜のエッジを利用した微細パタンを周期ｐｄｅ形成するための位相シフトマスク断面図
【図18】位相シフト膜のエッジを利用した微細パタン形成でパタン幅を制御するための手法の説明（a）位相シフト膜のエッジに社交対を入れたマスクの断面図、（b）位相シフト膜のエッジを周期の細かい折り返し形状にしたマスクの平面図
【図19】位相シフト膜を用いると不要なパタンが形成される例
【図20】図19で示した不要なパタンを2枚のマスクを用いて除去する手法の説明
【図21】2枚のマスク間の合わせの位置ずれがあったときに形成パタンに与える悪影響の説明
【図22】マスク間の合わせずれに対処するため、R領域の決定にあたり微細パタンの軸方向に距離αだけ領域を広げる説明での形成したいパタン
【図23】マスク間の合わせずれに対処するため、R領域の決定にあたり微細パタンの軸方向に距離αだけ領域を広げる説明でのR領域の形成例
【図24】マスク間の合わせずれに対処するため、R領域の決定にあたり微細パタンの軸方向に距離αだけ領域を広げる説明でのR領域を矩形に形成した例
【図25】マスク間の合わせずれに対処するため、R領域の決定にあたり微細パタンの軸方向に距離αだけ領域を広げる説明での広げたR領域の例
【図26】マスク間に合わせずれに対処してない場合のシフタを設けるマスクのマスクパタン例
【図27】マスク間に合わせずれに対処してない場合のシフタを設けないマスクのマスクパタン例
【図28】図27及び図28のマスクを用いたときに、マスク間の合わせずてがあったときのパタン形成例。
【図29】R領域の決定に際して距離α領域を広げた場合にマスク合わせずれがあったときのパタン形成例
【図30】マスク間の合わせずれに十分な対応がなされていない場合に合わせずれが生じた場合の説明
（a）形成すべきパタン（b）マスク1の平面図（c）マスクの平面図（d）合わせずれがあったときの形成パタン
【図31】本発明によりマスク間の合わせずれに対処した場合の説明図
（a）マスク1のパタン平面図
（b）マスク2のパタン平面図
（c）合わせずれがないときの形成パタン
（d）Ｍ2がＭ1に対して右上にずれて転写されたときの形成パタン
（e）Ｍ2がＭ1に対して左下にずれて転写されたときの形成パタン

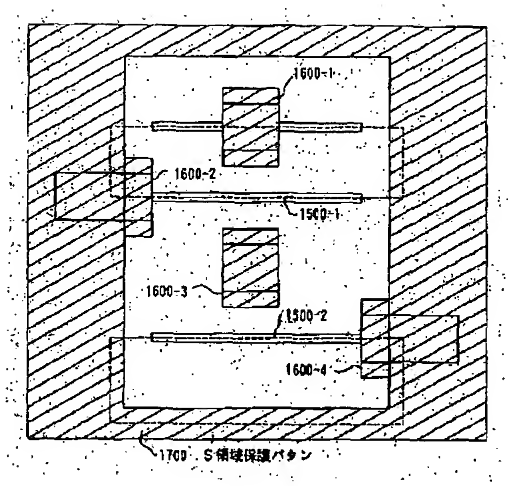
【図1】


与えられたパタンデータ
1000
微細パタン抽出処理
101
1100
微細パタンデータ
1200
通常パタンデータ
中心線抽出処理
102
中心線分データ
1250
103
R、S領域決定処理
S領域データ
R領域データ
105
R領域内通常パタン抽出処理
104
S領域内通常パタン抽出処理
シフタパタン生成処理
108
R領域内通常パタンデータ
1300
S領域内通常パタンデータ
1400
微細パタン保護処理
109
107
軸方向太らせ処理
106
幅方向太らせ処理
1500
M1用シフタパタンデータ
1700
M1用S領域保護パタンデータ
1600
M1用R領域パタンデータ
M2用微細パタン保護パタンデータ
2500
M2用R領域パタンデータ
2600
M2用S領域パタンデータ
2700

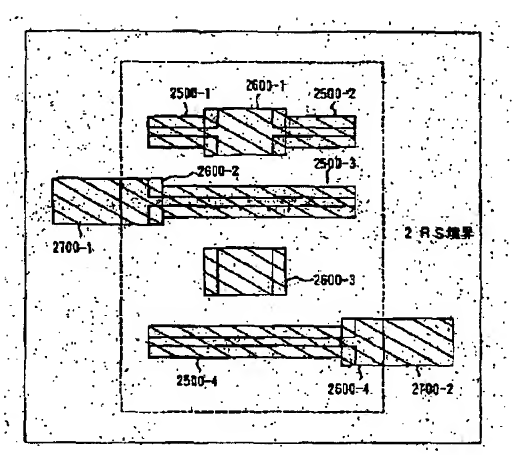
【図2】


1000
入力パタン
4 パタン形成領域

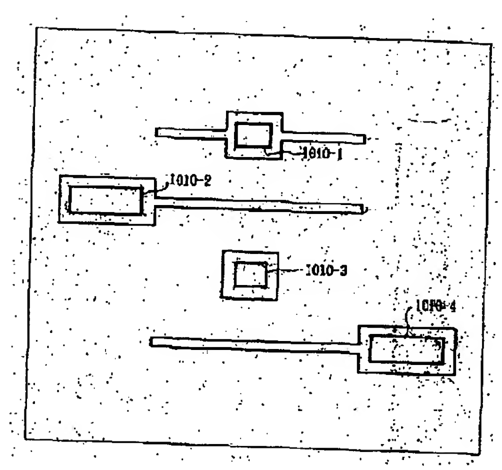
【図3】


1600-1
1600-2
1500-1
1600-3
1500-2
1600-4
1700 S領域保護パタン

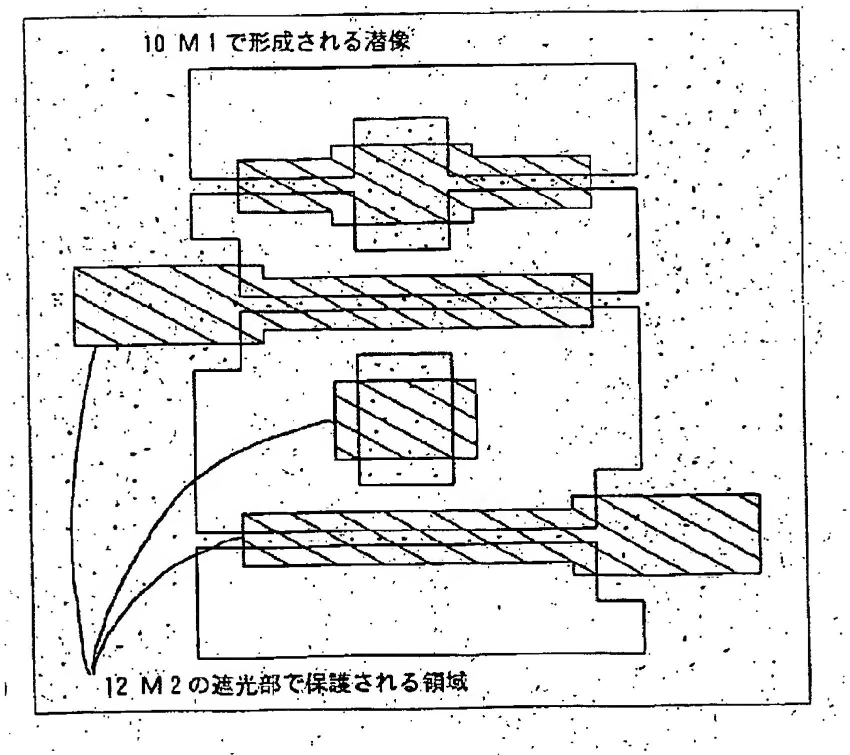
【図4】


2500-1
2600-1
2500-2
2600-2
2500-3
2700-1
2600-3
2500-4
2600-4
2700-2

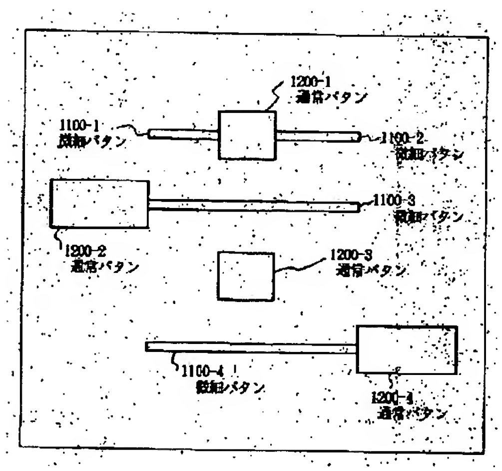
【図7】


1010-1
1010-2
1010-3
1010-4

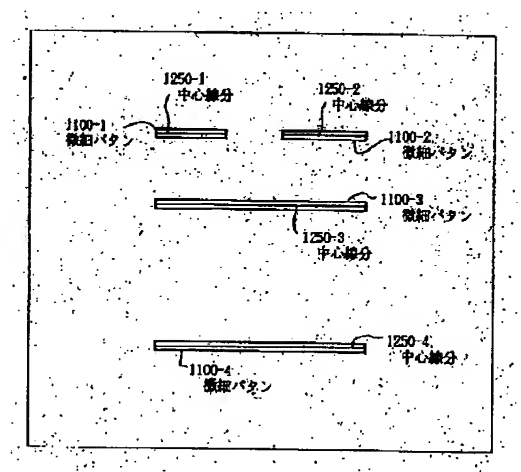
【図5】


10 M1で形成される潜像
12 M2の遮光部で保護される領域

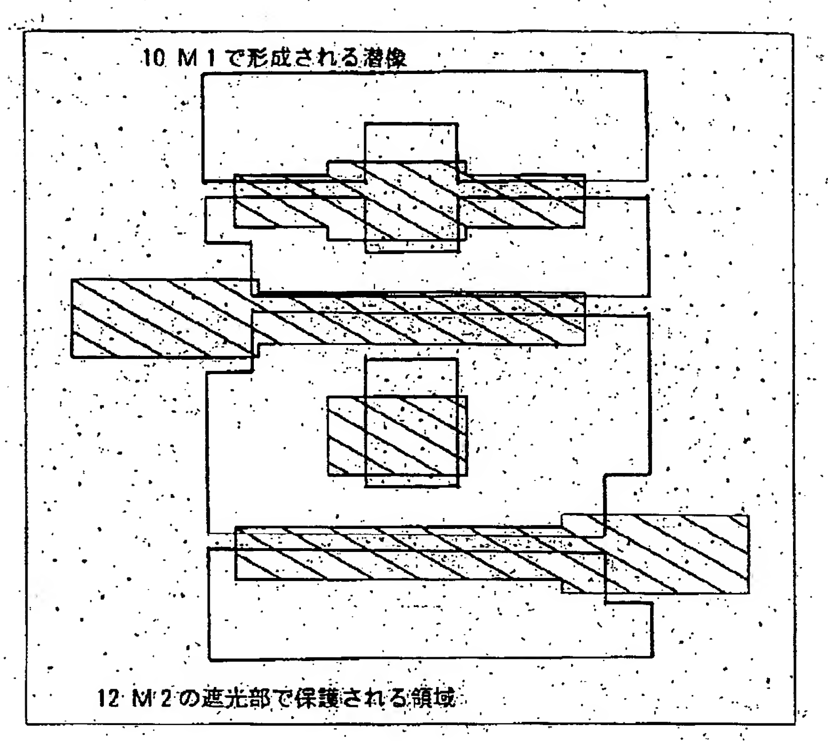
【図8】


1200-1
通常パタン
1100-1
微細パタン
1100-2
微細パタン
1100-3
微細パタン
1200-2
通常パタン
1200-3
通常パタン
1100-4
微細パタン
1200-4
通常パタン

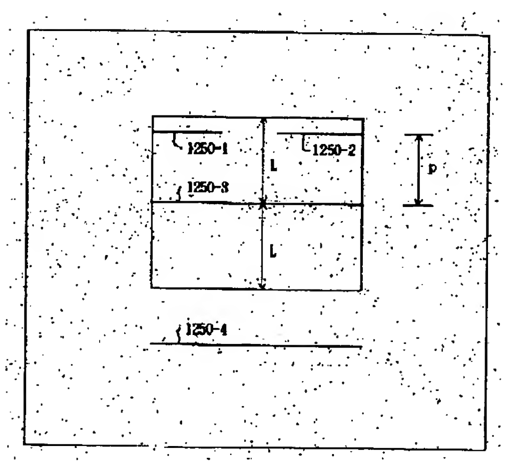
【図9】


1250-1
中心線分
1250-2
中心線分
1100-1
微細パタン
1100-2
微細パタン
1100-3
微細パタン
1250-3
中心線分
1250-4
中心線分
1100-4
微細パタン

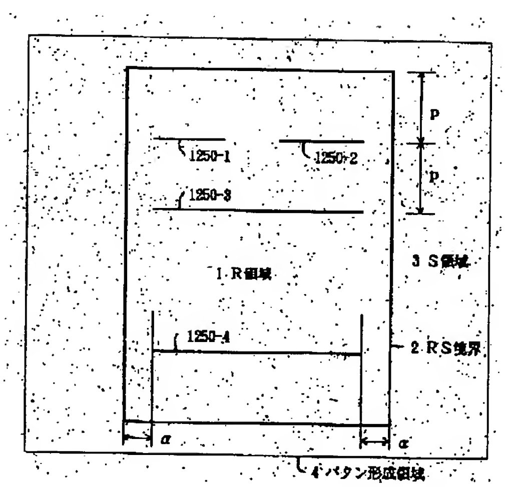
【図6】


10 M 1で形成される潜像
12 M 2の遮光部で保護される領域

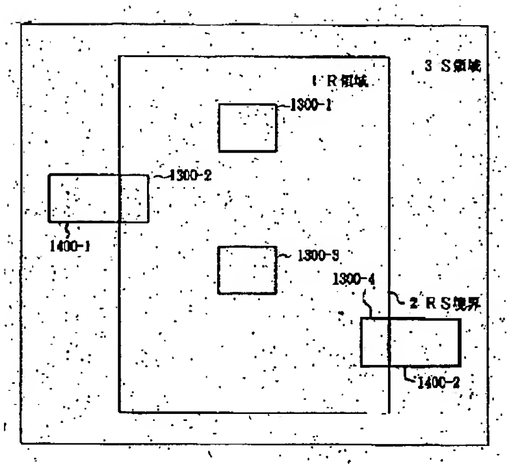
【図10】


1250-1
1250-2
1250-3
L
L
p
1250-4

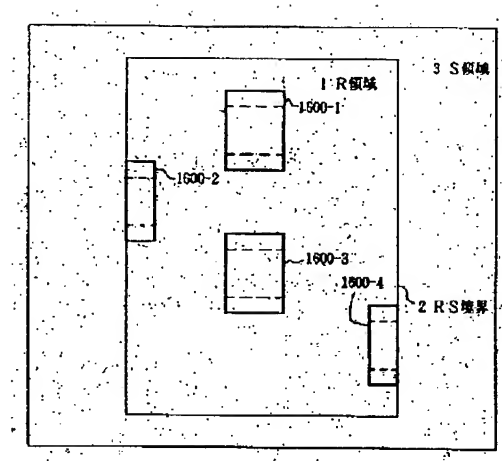
【図11】


p
p
1250-1
1250-2
1250-3
1 R領域
3 S領域
1250-4
2 RS境界
α
α
4 パタン形成領域

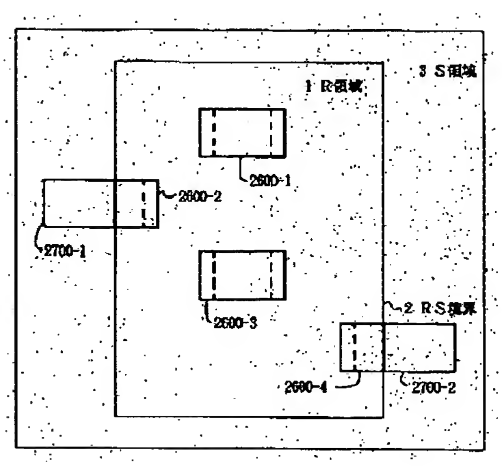
【図12】



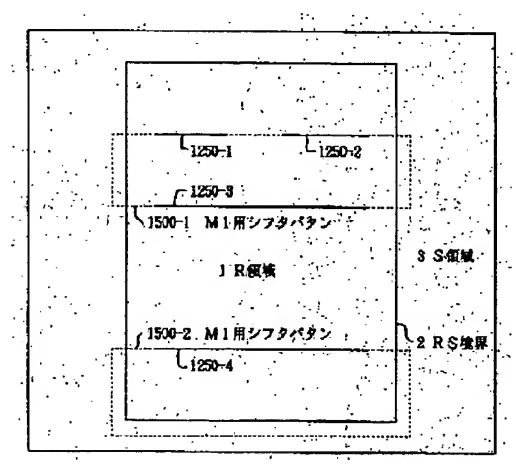
【図13】



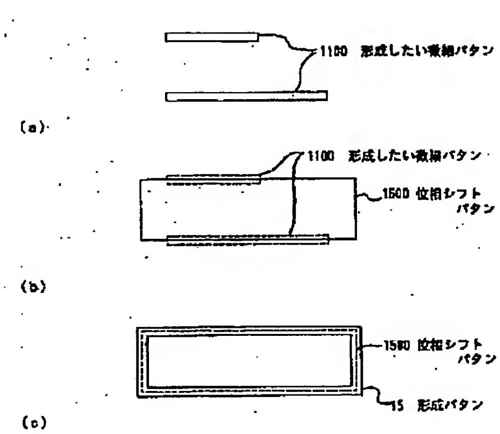
【図14】



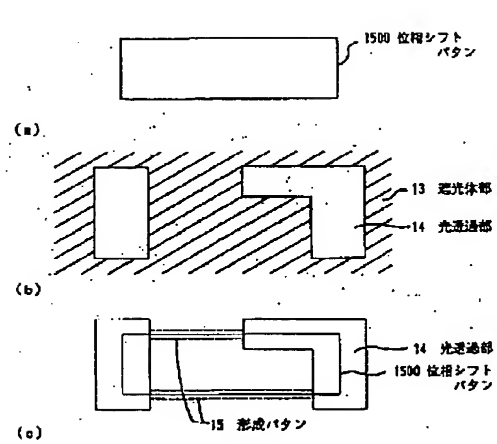
【図15】



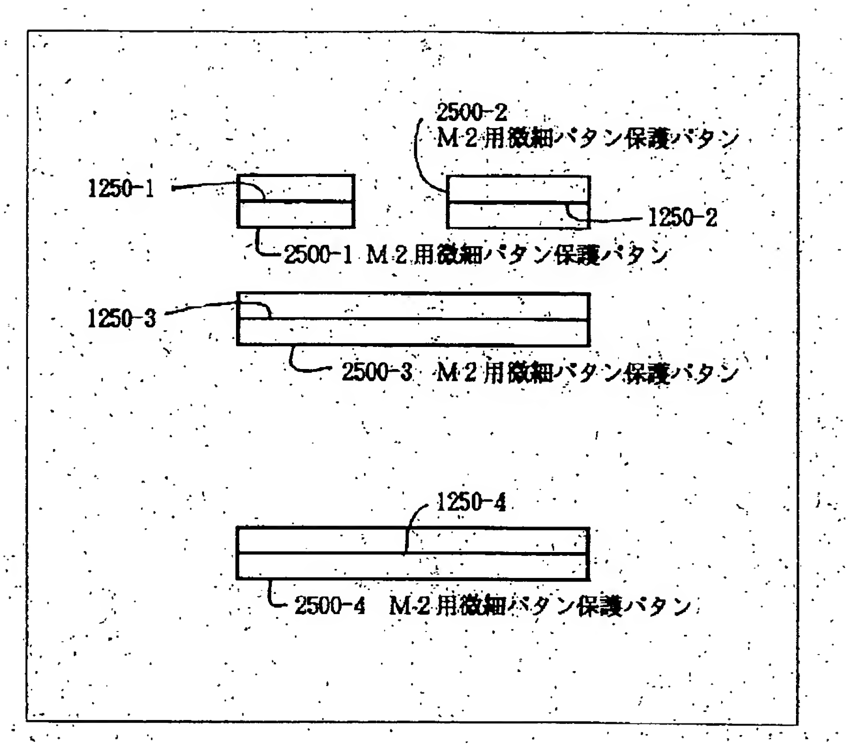
【図19】



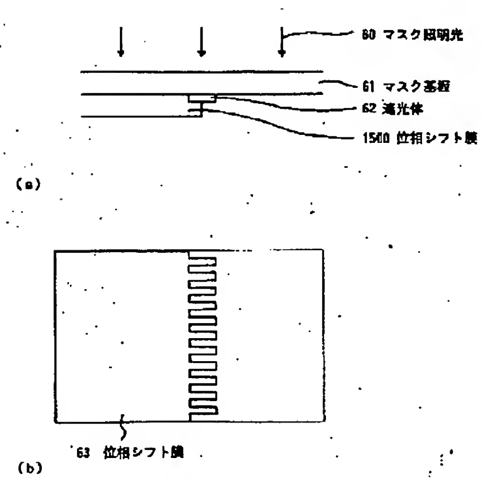
【図20】



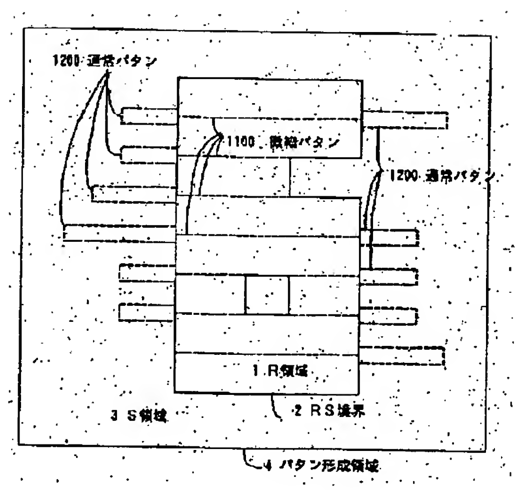
【図16】


2500-2
M 2 用微細パタン保護パタン
1250-1
1250-2
2500-1 M 2 用微細パタン保護パタン
1250-3
2500-3 M 2 用微細パタン保護パタン
1250-4
2500-4 M 2 用微細パタン保護パタン

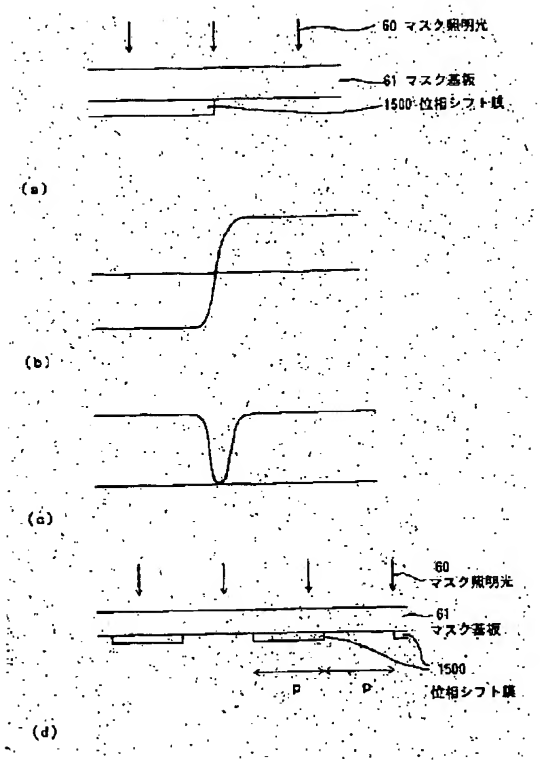
【図18】


60 マスク照明光
61 マスク基板
62 遮光体
1500 位相シフト膜
(a)
63 位相シフト膜
(b)

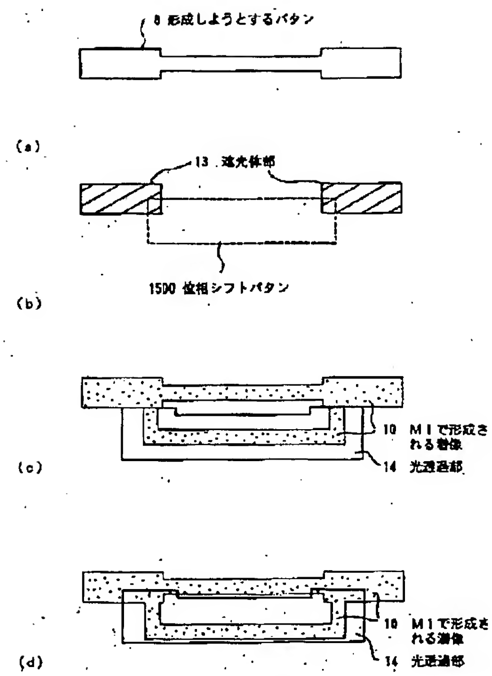
【図23】


1200 通常パタン
1100 微細パタン
1200 通常パタン
1 R領域
3 S領域
2 RS境界
4 パタン形成領域

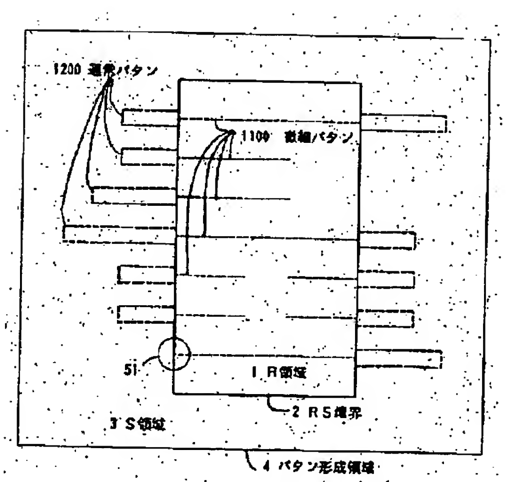
【図17】



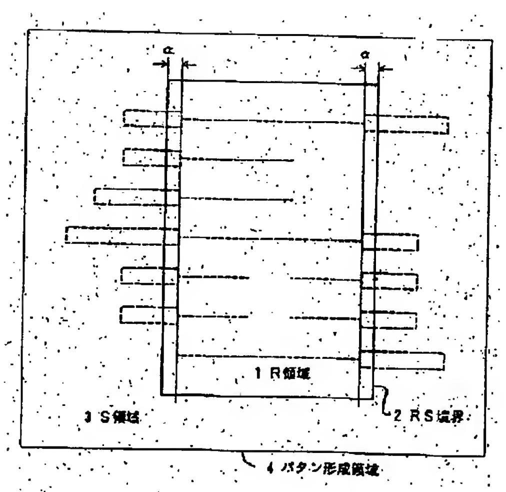
【図21】



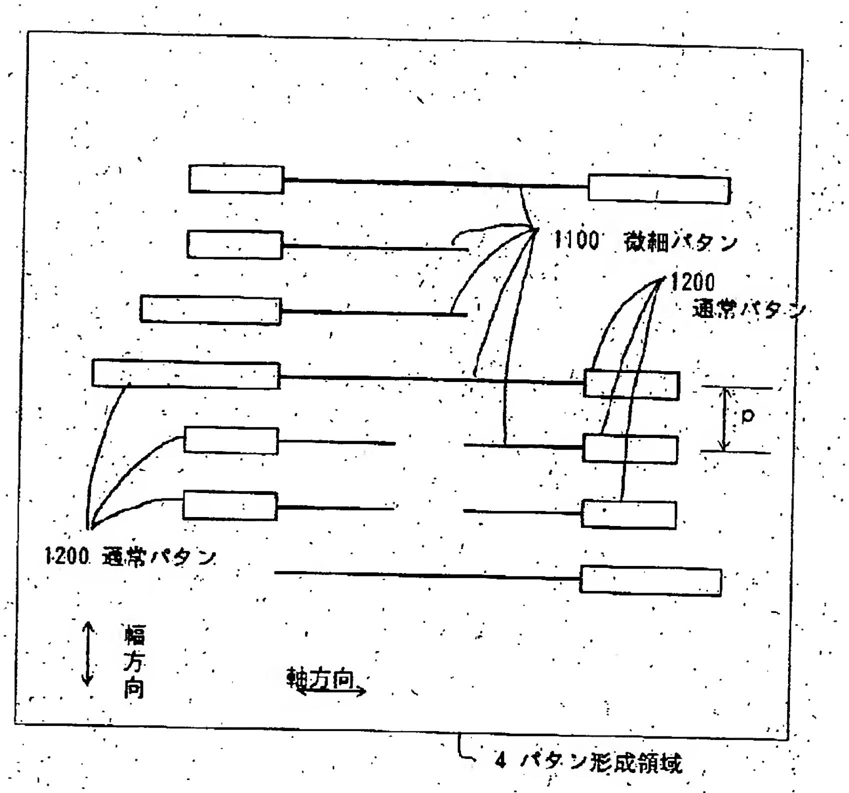
【図24】



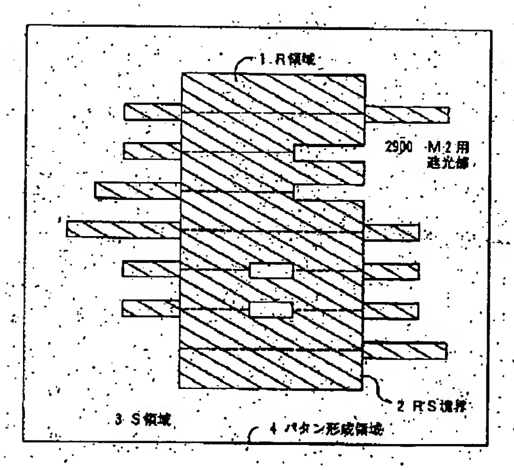
【図25】



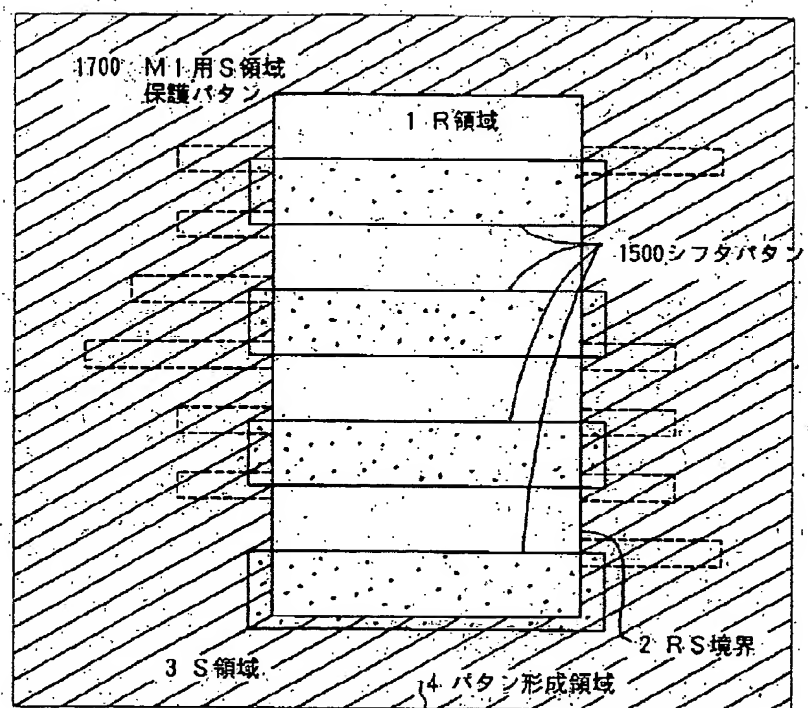
【図２２】


1100 微細パタン
1200
通常パタン
p
1200 通常パタン
幅方向
軸方向
4 パタン形成領域

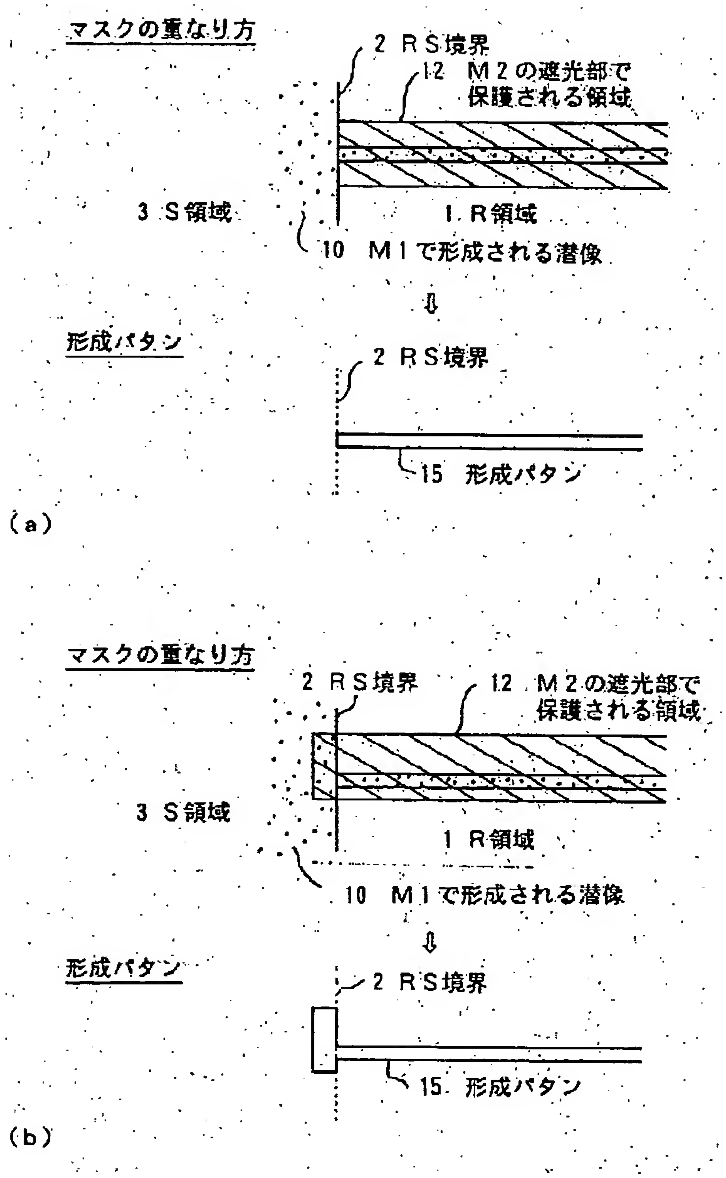
【図２７】


1 R領域
2900 M2用
遮光部
2 RS境界
3 S領域
4 パタン形成領域

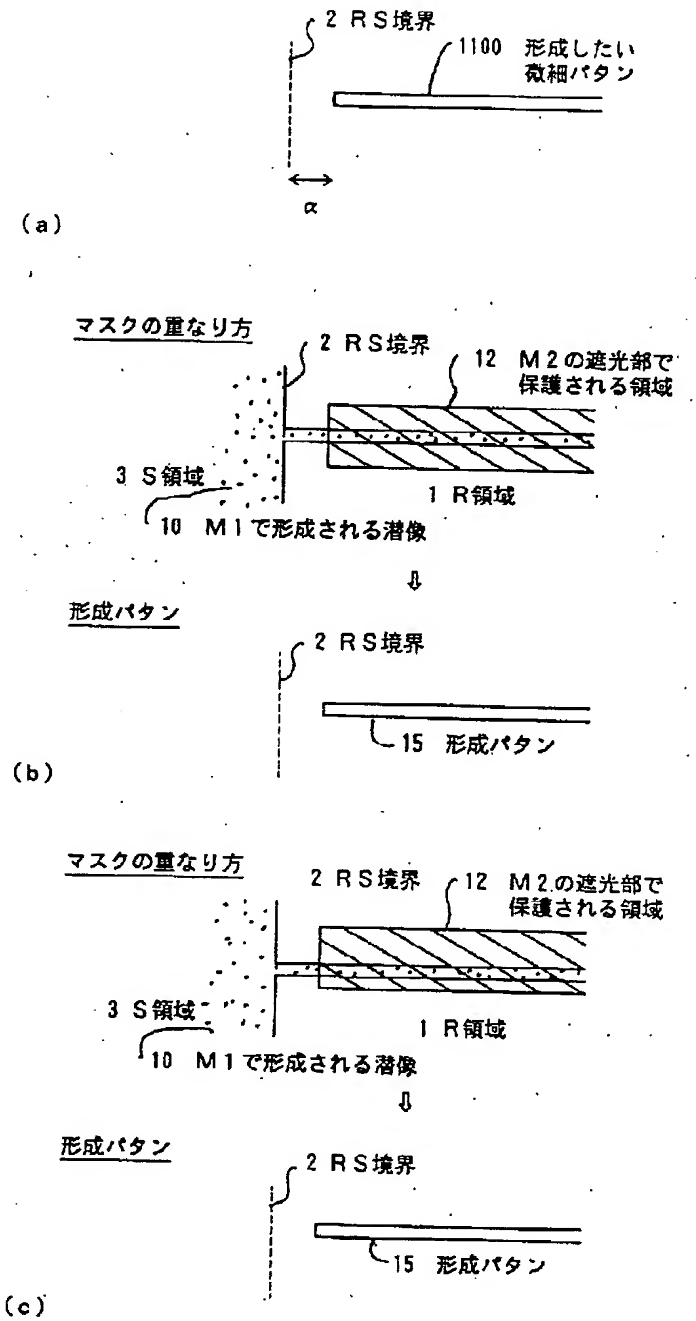
【図２６】



【図28】

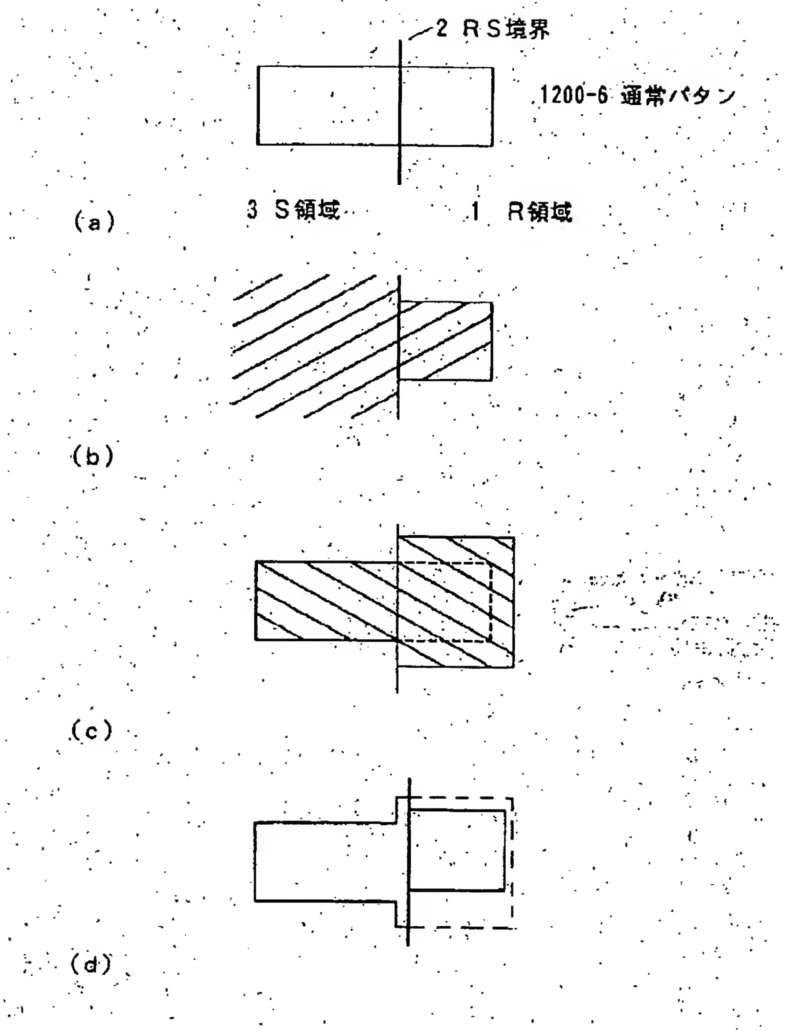

マスクの重なり方
2 RS境界
12 M2の遮光部で保護される領域
3 S領域
1 R領域
10 M1で形成される潜像
形成パタン
2 RS境界
15 形成パタン
(a)
マスクの重なり方
2 RS境界
12 M2の遮光部で保護される領域
3 S領域
1 R領域
10 M1で形成される潜像
形成パタン
2 RS境界
15 形成パタン
(b)

【図２９】

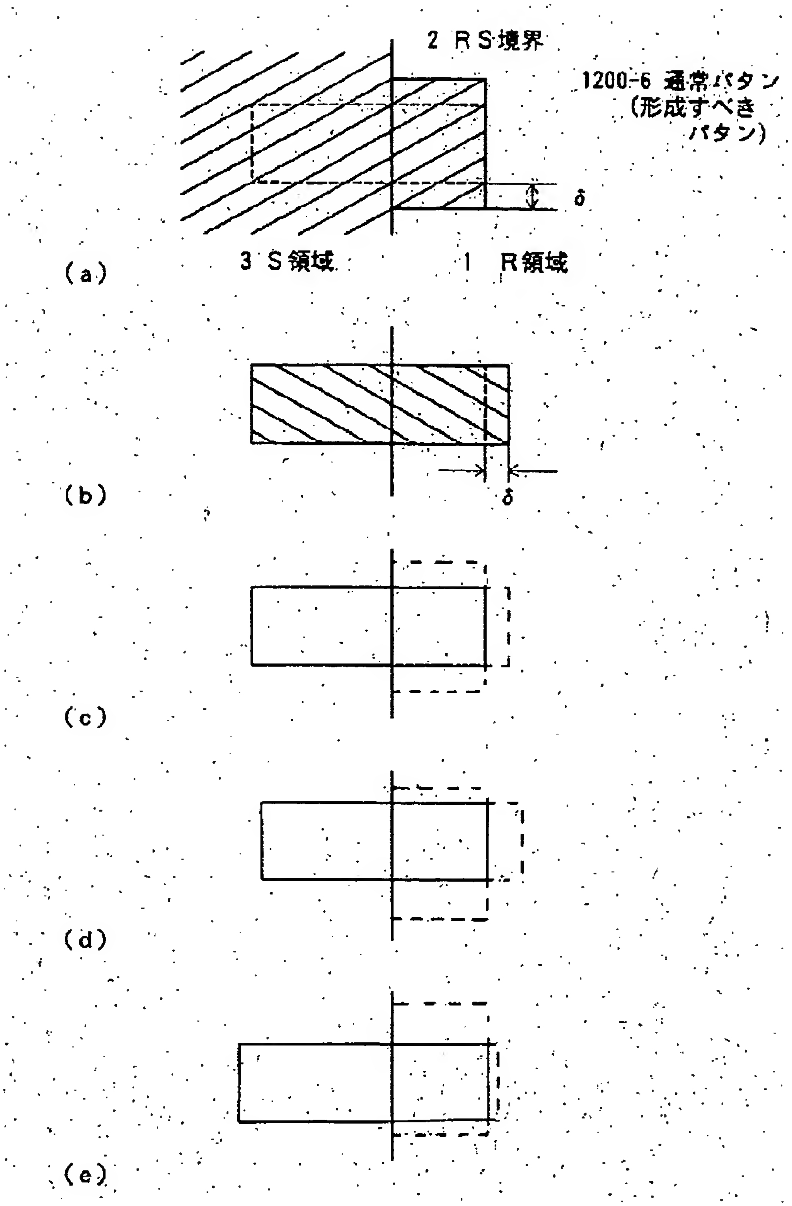


2 RS境界
1100 形成したい微細パタン
α
(a)
マスクの重なり方
2 RS境界
12 M2の遮光部で保護される領域
3 S領域
1 R領域
10 M1で形成される潜像
形成パタン
2 RS境界
15 形成パタン
(b)
マスクの重なり方
2 RS境界
12 M2の遮光部で保護される領域
3 S領域
1 R領域
10 M1で形成される潜像
形成パタン
2 RS境界
15 形成パタン
(c)

【図30】



【図31】



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(57) [Abstract] (Revised)

[Purpose]

To facilitate the automatic generation of mask patterns in a multilayer transfer method, and, furthermore, to provide a mask pattern that reduces the effect of misalignment between multiple masks.

[Constitution]

In multiple-exposure pattern formation that includes exposure by using mask M1 that contains phase-shift pattern 1500 as well as exposure that removes unnecessary patterns resulting therefrom, the exposure region is divided into two regions: a region with the fine pattern 1100 required by a phase shifter and a region 3 that is not 103[1]; a shifter is provided in one mask; region 1 contains a mask shifter pattern with edges corresponding to the fine pattern and a pattern that corresponds to other pattern 1600; a shielding mask pattern [is used for] region 3; and a separate shifter-less mask is generated automatically so that it has a normal pattern that forms pattern 2600 that exists in region 3 and a pattern that removes unnecessary patterns in the pattern of the shifter formation region. Furthermore, in one mask, the mask pattern is thickened in one axial direction, and in another mask, the mask pattern is thickened in the direction orthogonal thereto.

[1] Translator's note: "103" appears here in the original Japanese patent.

[Claims]

[Claim 1]

A method for processing mask pattern data, characterized in that,
in pattern formation that forms the pattern of one layer by means of multiple exposures, including an exposure that uses a mask containing a pattern that is phase-shifted so that the phase difference of the light transmitted through both sides of the fine pattern to be formed is approximately π, as well as an exposure for removing the unnecessary patterns resulting therefrom,
it includes, in order to form the said fine pattern, a first process that sets up the first region required to transmit light with phase differences, and a second process that divides all formed patterns or all patterns other than the said fine pattern into regions inside and outside of the said first region.

[Claim 2]

The method for processing mask pattern data described in Claim 1, characterized in that, when the said first region is determined, the boundary of the said first region is set so that the length of the fine pattern formed with the phase difference of the light transmitted through both sides approximately [equal to] π is longer, on both sides and in the axial direction of the fine pattern, than the length of the fine lines formed ultimately, by only the distance equal to the overlap error resulting from the superposition of multiple masks.

[Claim 3]

A photomask characterized in that,
in a photomask that forms the pattern of one layer by means of multiple exposures, including an exposure that uses a mask containing a pattern that is phase-shifted so that the phase difference of the light transmitted through both sides of the fine pattern to be formed is approximately π, as well as an exposure for removing the unnecessary patterns resulting therefrom,
when the pattern that must be formed by using phase-difference light is called the fine pattern, when the pattern, other than the fine pattern, formed by transferring a

conventionally used mask shield is called the normal pattern, and when the longitudinal direction in which extend the fine lines of the fine pattern is called the axial direction and the direction orthogonal to the axial direction is called the width direction,
in the mask that forms a fine pattern for the pattern in the first region, which is necessary to transmit phase-difference light in order to form the said fine pattern, the normal pattern in the said first region has dimensions such that, in the axial direction, it has the length of the pattern ultimately formed by the said multiple exposures, and in the width direction, [the dimension] extends, by a specified length, [beyond] the width of the pattern ultimately formed by the said multiple exposures; and in the other mask, the normal pattern within the said first region has dimensions such that, in the axial direction, it is longer, by a specified length, than the pattern ultimately formed by the said multiple exposures, and in the width direction, it has the width of the pattern ultimately formed by the said multiple exposures.

[Claim 4]

A photomask characterized in that,
in a photomask that forms the pattern of one layer by means of multiple exposures, including an exposure that uses a mask containing a pattern that is phase-shifted so that the phase difference of the light transmitted through both sides of the fine pattern to be formed is approximately π, as well as an exposure for removing the unnecessary patterns resulting therefrom,
the boundary of the said first region is set so that the length of the fine pattern formed with the phase difference of the light transmitted through both sides approximately [equal to] π is longer, by only a specified distance, on both sides and in the axial direction of the fine pattern, than the length of the fine lines formed ultimately by means of the said multiple exposures.

[Detailed Explanation of the Invention]

[0001]

[Industrial Field of the Application]

The present invention relates to a mask pattern creation method, mask, and pattern formation method [used when] forming fine patterns (e.g., an LSI) on a wafer (substrate) by using a projection lens.

[0002]

[Prior Art]

High resolutions have been required conventionally in projection exposure techniques that form fine patterns (e.g., an LSI). As a result, the projection lenses of projection aligners have a resolution near the theoretical limit determined by the wavelength of light. Furthermore, in recent years, the phase-shift method has been studied as a method of transferring finer patterns. In the phase-shift method, it is possible to increase the resolution by adding a transparent film such that a phase difference approximately equal to π is produced in the transmitted light, in the optically transmissive part of a mask placed in the plane of the projection lens. This phase-shift method can be classified into several techniques. However, as a method of forming isolated fine line patterns, there is a pattern formation method that utilizes the phase difference of approximately π that occurs at the edges of phase-shift film. This method will be explained with reference to Figure 17. Figure 17(a) shows part of a cross-section of a phase-shift mask. [In the figure,] 60 is the light that illuminates the mask, 61 is the mask substrate, and 1500 is the phase-shift film. In the figure, a boundary edge (shifter edge) is present between the area where phase-shift film 1500 exists and the area where it does not exist. The complex amplitude distribution of the light that passes through this mask is as shown in Figure 17(b). The corresponding light intensity distribution is as shown in Figure 17(c). Here, it is assumed that, in Figures 17(a), (b), (c), the horizontal axes coincide. In these figures, the light intensity of the corresponding area is 0 because the phase varies by π at edges. This forms a very fine shield part at the edges of the phase-shift film. For example, when using the g-line (wavelength: 436 nm) of a high-voltage mercury-vapor lamp, if the focal depth is taken into consideration, a width of

approximately 0.5 μm is the limit when transferring a shield pattern made of ordinary chromium or the like. When this shifter edge is used, it is possible to form a pattern with a width [as fine as] 0.2 μm. This line width is called the limit resolution line width. For this reason, it is expected that shifter edges will be applied to fine pattern formation.

[0003]

When utilizing shifter edges, two points should be added to the explanation: One [point] is the pattern density limit. When shifter edges are used, fine-width shield parts can be formed. For that purpose, however, phase-difference light must be transmitted to both sides of the shield part. This indicates that the spacing is limited when closely forming the two fine-width shield parts. The continuous formation of a shield part with width 0.2 μm and spacing p is shown in Figure 17(d). However, the spacing p of the shield part must be nearly 1 μm.

[0004]

The other point concerns the line width of the shield part. It is advisable to use shifter edges with phase difference π to obtain the finest line widths. This enables the use of a 0.2-μm line width. However, in the formation of actual LSI patterns, it sometimes is necessary to form minimum line widths obtained by transferring normal shields, that, for example, are narrower than 0.5 μm, but thicker than 0.2 μm, the dimension obtained by means of previous shifter edges. The method of forming line widths intermediate between these is shown in Figures 18(a), (b). [In the figure,] (a) is a cross-section of the phase-shift mask. A pattern width of a least the limit resolution line width can be achieved by inserting shields made of chromium or the like, at the shifter edges and then adjusting the shields' line widths. (b) indicates the planar structure of a phase-shift mask. A pattern with [a width] of at least the limit resolution line width can be achieved by providing fine dovetails[2] at the edge of the phase-shift film. Thus, if the pattern [has a width] at least equal to the limit resolution line width, even though it is less than the line width obtained by transferring a normal shield, it can be formed by using the shifter edge. In Figures 18(a), (b), also, of this document, this pattern formation method is called the shifter edge method.

[2] Translator's note: The Japanese world literally means "flap; loop back; turn back," but "dovetails" seems implied by the figure.

[0005]

The greatest problem of pattern formation by means of shifter edges is that fine patterns are formed at all edges. Figure 19 illustrates this. (a) is the fine pattern 1100 to be formed. (b) is the phase-shift mask that contains phase-shift pattern 1500 for forming the fine pattern shown in (a) by means of the shifter edge method. (c) is the pattern 15 formed by using the mask shown in (b). It is evident that unnecessary patterns are formed at the shifter edges. To prevent the generation of this unnecessary pattern, the following have been proposed: ① a multistage technique that uses a multistage phase-shift film and ② a multilayer transfer method that uses multiple masks.

[0006]

In the technique that uses a multistage phase-shift film, multiple phase-shift films with different phases are used and parts requiring fine patterns have the phase difference π on both sides. In parts not requiring pattern formation, however, the phase difference on both sides is 60°, for example, so no pattern is formed. In this method, the desired pattern can be formed by means of one phase-shift mask. However, it is necessary to create multistage phase-shift film, so mask production is complex, which is a fatal defect.

[0007]

The multilayer transfer method that utilizes two masks will be explained [next, with reference to] Figures 20(a), (b), and (c). The pattern to be formed is shown in Figure 19(a). Mask 1 that has the same phase-shift film as in Figure 19(b) is shown in Figure 20(a), and mask 2 that consists of only a shield is shown in (b). The state in which these two masks are superposed in order to form a pattern is shown in (c). When developing is performed after exposing by means of two masks, only in the parts shielded by both masks are patterns formed as the ultimate shield parts. The pattern shown by the broken lines in (c) corresponds to this. That is, when a fine pattern is formed at the boundary edges, where mask 1's phase difference is π, mask 2 is used to expose and remove the unnecessary parts. This multilayer transfer method has the advantage of simple mask production, because it uses only one type of phase-shift film, which has a transmitted light phase difference of π.

[0008]

[Problems That the Invention Is to Solve]

Conventionally, it was impossible to manually lay out shifters and shield parts for individual patterns, with this multilayer transfer method as the method for removing the unnecessary patterns. However, a method of automatically generating and laying out these patterns, when patterns are mixed in a complex manner, has not been proposed. Also, when, in actual pattern formation processes, an attempt is made to form the pattern for one layer by means of two exposures that use different masks, it is impossible to avoid an alignment error between the two exposures. An example of the deformation experienced by the pattern after a relative shift occurred in two exposures is shown in Figure 21. The pattern 8 to be formed is shown in Figure 21(a). (b), the first mask (M1) used for this purpose, comprises shield part 13 and phase-shift pattern 1500. In (c), the second mask (M2) is superposed, without shifting, on pattern 10, which was obtained as the latent image as a result of the exposure with M1. The latent image in the region corresponding to the light-transmission part 14 of M2 is removed, which enables the formation of the target pattern shown in (a). By contrast, in (d), transfer was performed with M2 shifted upward relative to M1. The light-transmission part on M2 for removing the unnecessary patterns formed by M1 overlaps the latent image of the pattern to be formed, so the normal pattern part on both sides of the fine pattern undergoes deformation that causes part of it to be lost, thereby producing a constriction in the fine pattern part.

[0009]

The present invention provides a method of automatically generating mask patterns, and was [developed] while taking into consideration the aforementioned points. Its purpose is to provide a mask pattern creation method and its mask, that minimizes the effects of alignment error between multiple used masks, in the formation of the pattern of one layer by using multiple masks, when forming the pattern of a circuit (e.g., an LSI) by using a phase-shift method; and, furthermore, to provide a method of automatically generating a mask pattern that contains a shifter pattern, even though it will impose restrictions on part of the applied LSI, etc.

[0010]

[Means of Solving the Problems]

The terminology used herein will be explained first. Of the formed patterns, the narrow pattern formed by using shifter edges is called the fine pattern 1100, and the pattern formed by transferring the shield on the mask, as conventionally, is called the normal pattern 1200. The formed pattern (i.e., provided pattern 1000) is always classified as either a fine pattern 1100 or a normal pattern 1200. For example, it is possible to classify a pattern with a width of at least 0.5 μm as a normal pattern 1200, and [one with a width of] less than 0.5 μm as a fine pattern 1100. Also, fine pattern 1100 should be sufficiently long (e.g., at least 4 times the width). Its lengthwise direction is called the axial direction, and the direction orthogonal thereto is called the width direction. Also, in order to form a fine pattern by using the shifter edge method, a region where light with phases separated by approximately π passes through both sides of the fine pattern is necessary, and the region is called phase-specified region R 1 or region R 1. In region 4 (e.g., the chip region) where a pattern is to be formed, the part other than region R is called region S 3. The entire pattern formation region 4 consists of region R 1 and region S 3, and region R 1 and region S 3 do not overlap. Also, the boundary of region R and region S is called the R-S boundary 2. These are illustrated in Figures 22, 23, and 24. Fine pattern 1100 originally had patterns with width. In Figure 22, however, it is represented as a linear segment to avoid figure complexity.

[0011]

First, the present invention will be explained schematically. Although a multilayer transfer method is used, here it is limited to two exposures by using two masks, with the first [mask] (M1) having phase-shift film (i.e., the shifter) and the second [mask] (M2) being the shifter-less mask. That is, in the first exposure a fine pattern that uses the shifter edges is formed, and in the second exposure the necessary parts of the formed fine pattern are protected and the unnecessary parts are exposed and thereby removed.

[0012]

Here, to facilitate explanation, etc., the following three prerequisites will be introduced:
Prerequisite 1: Fine pattern 1100 is entirely parallel to the x-axis.
Prerequisite 2: The spacing of the mutually adjacent center lines of fine pattern 1100 [equals] either a uniform value p or an integral multiple of p.

[0013]

Prerequisite 3: There is only one type of line width in fine pattern 1100. This line width d equals the width of the pattern formed by the shield part, which is formed when shifters of width p are lined up with spacing p.

The pattern of Figure 22 satisfies these conditions. Now, one purpose of the present invention is to automatically generate, from the provided pattern, the M1 shifter pattern, the shield pattern, and the M2 shield pattern. For this purpose, the phase-assignment region R 1 is computed from provided pattern 1000, and the normal pattern 1200 is divided into pattern 1300 that exists inside region R and pattern 1400 that exists outside region R (i.e., in region S).

[0014]

When Figure 22 is regarded as the provided pattern 1000, the regions shown in Figures 23 and 24, for example, are considered to be phase-assignment region R 1. In any case, although omitted from these figures, the phase-shift film that produces the phase difference π is present periodically, as shown in Figure 26. In both Figures 23 and 24, region R 1 is [the region] from the center line of the fine pattern to the region separated by distance p, at the top of the top fine pattern to the bottom of the bottom fine pattern.

[0015]

In Figure 23, because only the phototransmissive part required to form fine pattern 1100 is considered to be region R 1, region R 1 has a complex shape corresponding to fine pattern 1100. By contrast, in Figure 24, region R 1 is a rectangular region, and its x-direction boundary is determined so that it can cover the most extensive region, from among the boundaries required to form fine pattern 1100. Here, an easily computed

rectangular area is adopted as region R 1. The concrete procedure for determining region R will be discussed in the embodiment.

[0016]

Once region R 1 has been determined, it is easy to divide provided pattern 1000 into pattern 1300 that exists within region R and pattern 1400 that exists within region S. As a result, the first mask M1 is a planar structure such as [the one] shown in Figure 26. Region S 3 is exposed and protected by forming a pattern (only a fine pattern in Figure 26) containing the fine pattern in region R 1. In Figure 26, the dotted region is shifter 1500. Fine pattern 1100 is formed at its edges. Region 1700, which is covered with diagonal lines descending to the left, is the shield part. On the other hand, in the second mask M2, the normal pattern of region S 3 is formed, as in Figure 27. Region R 1 is exposed and protected, after which the unnecessary fine pattern formed by M1 is exposed and removed. The region covered by diagonal lines descending to the right is the shield part.

[0017]

Thus, the introduction of region R 1 separates the region forming the fine pattern and the other regions. This enables the independent formation of patterns within each region, which enables the automatic generation, from provided pattern 1100, of the pattern within each region containing a shifter. Although defects remain as is in Figures 26 and 27, even in the improved technique discussed hereinafter the introduction of region R 1 plays a significant role in the automatic generation of patterns.

[0018]

Another purpose of the present invention is to maximize the faithfulness of the pattern transfer, even after a relative shift between multiple masks. If M1 and M2 shown in Figures 26 and 27 can be transferred without error, it is possible to form the sought provided pattern 1100. Actually, however, a relative shift exists between M1 and M2. That is, R-S boundary 2 of M1 and R-S boundary 2 of M2 do not overlap. As a result, when consideration is given to the case where the position of M2 is shifted upward and to the right relative to M1, for example, the top and right edges of region R 1 of M2 overlap region S of M1, and both M1 and M2 are shielded and unexposed, so unnecessary

patterns are formed. This indicates that exposure must be performed from both M 1 and M 2 to the part to be exposed near R-S boundary 2.

[0019]

In M2 of Figure 27, to protect the latent image of the fine pattern required for region R 1, the entire region, except for unnecessary latent image parts, is regarded as the shield part. However, only the pattern part within region R must be protected. Consequently, only the region in which the pattern part of region R is enlarged somewhat by only the anticipated amount of misalignment—so that the pattern part is unexposed even if the mask shifts—is regarded as the shield part; the other part is regarded as the transmission part. In this manner, for a part where no pattern exists at the boundary of region R (e.g., the upper edge of region R in Figure 27), unexposed patterns no longer occur, even after an alignment shift.

[0020]

Furthermore, the present invention will be explained for a method of dealing with mask misalignment, when a pattern is present at R-S boundary 2. First, the case where the edge of a fine pattern is on R-S boundary part 2 will be discussed. The circled part 51 in Figure 24 corresponds to this. Figure 28(a) shows the case of no mask misalignment, for pattern 15 obtained by enlarging this part and overlapping latent image 10 formed by M1 and part 12 protected by M2; (b) shows the case where M2 is shifted to the left. In Figure 28(a), where there is no misalignment, the planned pattern is formed. However, in (b), where there is misalignment, the tip of obtained fine pattern 15 is expanded. To eliminate this phenomenon, when the right and left edges of region R 1 are determined, as shown in Figure 25, the regions that extend by just α beyond the sections present in the fine pattern, on both sides in the axial direction, is considered region R 1. Also, for protection pattern 2500 in M2 for the fine pattern formed by M1, although thickening was performed in the width direction of fine pattern 1100 in order to allow for misalignment, thickening should not be performed in the axial direction. Figure 29 is the figure resulting from such processing. Figure 29(a) shows the positional relationship between the fine pattern 1100 to be formed and the R-S boundary 2. (b) and (c) show, in the cases of misalignment and no misalignment, the overlap between latent image 10 formed by M1 and part 12 protected by M2, as well as resulting pattern 15. Whether or not there is misalignment, a faithful pattern could be transferred. In the formation of fine pattern 1100, by extending

region R 1 by α on both sides in the axial direction, even if mask misalignment occurs pattern deformation does not occur, and it is possible to determine the fine pattern's y-direction position by means of M1 and [its] x-axis direction position by means of M2.

[0021]

Next will be discussed the case of Figure 30(a), where region R is extended by α in the axial direction, so that normal pattern 1200 is present at the R-S boundary. First to be discussed will be the type of pattern deformation in the conventional case when misalignment is not dealt with. Figure 30(b) and (c) show the M1 and M2 patterns, respectively. In M2, the normal pattern within region R 1 is enlarged by thickening it uniformly. As aforementioned, this is in order to protect the latent image formed by M1, even in the event of mask misalignment. If transfer occurs without alignment error, the pattern of Figure 30(a) is obtained. However, after a transfer with M2 shifted to the lower left, for example, as shown in Figure 30(d), in formed pattern 15 the thickened part in region R 1 invades region S 3, thereby causing pattern projections and interfering with other adjacent patterns.

[0022]

In the present invention, to avoid such problems, for a normal pattern within region R, in M1 one side is thickened by just δ only in the width direction (y-direction). In M2 one side is thickened by just δ only in the axial direction (x-direction). The M1 and M2 patterns, which were obtained by applying the present invention to the pattern of Figure 30(a), are shown in Figures 31(a) and (b). The cases where M1 and M2 were transferred without alignment error, where M2 was shifted to the upper right, and where M2 was shifted to the lower left are shown in Figures 31(c), (d), and (e), respectively. In all cases, the formed pattern shapes produced no constriction or projection, so they almost faithfully reflect the design pattern. This is because the normal pattern within region R was separated and thickened in the up and down directions in M1 and in the left and right directions in M2, so if misalignment occurs, only the left and right sides (in the example of Figure 30, the right side) of the normal pattern within the region are determined by M1, while the remaining sides are determined by M2, regardless of whether they are inside or outside the region.

[0023]

[Function of the Invention]

In pattern formation in which the pattern of one layer is formed by means of multiple exposures, including exposure using a mask containing a pattern that is phase-shifted so that the phase difference of the light that passes through both sides of the fine pattern to be formed is approximately π, as well as exposure for removing the unnecessary patterns resulting therefrom, the regions commonly shielded from exposure by multiple masks remain as the pattern. By dividing the exposed region into a fine-pattern region that is required by the phase shifter and a region that is not, it is easily possible to automatically generate the shifter pattern and the mask pattern by means of two masks, so that one provides a shifter, and in the region with the fine pattern, it has a mask shifter pattern with edges corresponding to the fine pattern and a mask pattern corresponding to the other pattern; and the region without the fine pattern is the shading mask pattern, and in the other mask, a shifter is not provided, and two patterns are provided: the normal mask pattern that forms the pattern present in the region not provided with a shifter and the mask pattern for removing the unnecessary patterns in the pattern of the region forming the shifter. Furthermore, because the formed pattern [consists of] the parts shielded by both masks, it is possible to markedly decrease the effect of inter-mask shifting on the formed pattern and thereby sharply increase the alignment yield, by thickening the mask pattern in one mask in one axial direction, and by thickening the mask pattern in the other mask in the direction orthogonal thereto.

[0024]

[Embodiment]

Next will be discussed an instance of the application of the present invention to a gate layer with the fine pattern formation required in LSIs. The embodiment's process flow is shown in Figure 1, and the provided input pattern data and the pattern data for the preparation of a mask created by using the present invention are shown in Figures 2 through 6. Figure 2, the input pattern data 1000 containing the fine pattern, satisfies the three prerequisites in the Means of Solving the Problems. Figures 3 and 4 [show] the two masks M1, M2 used to form the pattern of Figure 2. M1 has a shifter, while M2 lacks one. As aforementioned, the normal pattern is divided into region R and region S before the pattern is generated, so three types of pattern data are required to prepare the M1 mask:

shifter pattern data 1500, region R pattern data 1600, and region S protection pattern data 1700. Similarly, three types of pattern data are required to prepare the M2 mask: pattern data 2500 for protecting the fine pattern created by the M1 shifter, region R pattern data 2600, and region S pattern data 2700. These patterns are shown in Figures 3 and 4.

[0025]

Figure 1 shows the flow of the process [used to] create, from input pattern data 1000, pattern data 1500, 1600, 1700, 2500, 2600, and 2700 (i.e., three types each for M1 and M2, for a total of six types). Rectangles with rounded corners indicate data processing. Their inputs and outputs are pattern data, which are indicated by ordinary rectangles. Nine types of data processing (i.e., 101 to 109) are required, and details of their respective processing and their concrete implementation method will be discussed hereinafter. Furthermore, the implementation method discussed here is but one technique, and [it] is not limited thereto.

[0026]

The data processing discussed hereinafter utilizes mask data that is two-dimensional image data. Contour extraction for two-dimensional image data, uniform width thickening and thinning (called resizing), black-white inversion processing for the chip region, and product set operations for multiple input data, etc., generally have already been processed by means of the design rule check (DRC) of the LSI mask pattern data or the data processing for drawing a mask by using an electron beam. Consequently, explanations of the specific techniques for generally performed processing are omitted. For the concrete technique, refer to "Review of the Automation of LSI Mask Pattern Data" (*Nikkei Electronics*, April 28, 1980, pp. 90-107), for example.

[0027] <u>Fine Pattern Extraction Processing 101</u>

Provided pattern 1000 is divided into fine pattern 1100 and normal pattern 1200. If the fine pattern's width d is known, the following processing can be performed:

(1) Thin the provided pattern 1000 by distance d/2.
(2) Extract the contours.
(3) Thicken the results of (2) by distance d/2. The obtained results are normal pattern 1200.

(4) When normal pattern 1200 is subtracted from provided pattern 1000, the obtained results are fine pattern 1100 with width d.

[0028]

Figure 2 is regarded as provided pattern 1000. Figure 7 shows the images 1010-1 to 1010-5 for the results obtained by narrowing by distance d/2 and then extracting contours, for provided pattern 1000. Figure 8 shows the normal patterns 1200-1 to 1200-4 obtained by thickening, by distance d/2, images 1010-1 to 1010-4 as well as fine patterns 1100-1 to 1100-4 obtained based on these. Usually, the fine-pattern line width is already known. However, if it is unknown, the said processing is executed first, with d set to the maximum size conceivable for a fine pattern (e.g., 0.49 μm). Obtained fine pattern 1100 contains all patterns with a width equal to or less than 0.49 μm. Next, the same processing is executed after decreasing d somewhat. If this processing is repeated while sequentially reducing d somewhat, eventually the fine pattern will disappear and a zero set will result. The value of d immediately before this point agrees with the width of the fine pattern.

[0029] Center Line Extraction Processing 102

This processing [is used to] determined the fine pattern's center line segment 1250. From the assumptions, there is one type of fine pattern line width, and the line width is known from fine pattern extraction processing 101, so the processing is simple. The relationships between fine patterns 1100-1 through 1100-3 and center line segments 1250-1 through 1250-4 are shown in Figure 9.

[0030] Regions R, S Determination Processing 103

This processing [is used to] determine region R 1 and region S 3, based on the fine pattern's center line segment data 1250. It is assumed that there are n total center line segment data and that distance p at which the adjacent center line segment data are aligned is already known. This is because, even if unknown, they can be determined by analyzing the data.

(1) A rectangle of width 2L is created by thickening by distance L on both sides, in the width direction of center line segment data 1250.

(2) Based on the n rectangles obtained in (1), contour extraction processing is performed, the polygons formed by interconnecting the rectangles are numbered, and the polygon numbers are assigned to each rectangle making up the polygon.

(3) The n rectangle data are sorted by polygon number, and the rectangles forming the same polygon are removed, after which the minimum rectangular areas that can cover the polygonal region are sought.

(4) The rectangular areas sought in (3) are extended, by α, in each of the two axial directions, thereby forming new rectangular areas. If these new rectangular areas overlap or contact, the same polygon number is assigned to them, after which [the processing] returns to (3).

(5) Both sides in the width direction of the rectangular areas obtained in (4) are narrowed by L, after which each is thickened by p. The obtained region is region R 1.

(6) Region R 1 obtained in (5) is subtracted from the pattern formation region, to obtain region S 3.

[0031]

This processing determines region R by collecting the center line segments near each other. The processing in the present embodiment is explained in Figures 10 and 11. If center line segments 1250-1 to 1250-4 are considered to form width-2L rectangles and all are connected, a polygon results. Region R 1 in Figure 11 is determined by means of [steps] (3), (4), and (5) of the said processing, because no other polygon exists. In the processing of [step] (1), if the spacing of adjacent center line segment data is less than 2L, then two rectangles may be connected to form one polygon. Consequently, as shown in Figure 10, assuming $2p < 2L < 3p$, one region R results if the spacing of adjacent center line segment data is 2p max. If they are separated by 3p, this can be regarded as another region R.

[0032] Processing for Extracting the Normal Pattern within Region R 104 & Processing for Extracting the Normal Pattern within Region S 105

In the processing for extracting the normal pattern within region R 104, the normal pattern data within region R is determined easily by means of a product set operation on the normal pattern data and the region R data obtained in region R determination processing 103. The same applies to processing for extracting the normal pattern within region S 105. The normal patterns 1300-1 to 1300-4 within region R and the normal patterns 1400-1 to 1400-2 within region S are shown in Figure 12.

[0033] Width-Direction Thickening Processing 106

Normal pattern 1300 within region R is thickened by δ, in the width direction, on both sides. The results are shown in Figure 13. Normal patterns 1300-1 through 1300-4 within region R become M1 region R patterns 1600-1 through 1600-4. δ is the amount determined by the relative alignment accuracy for the two masks. For example, it [may be] considered to have the value 0.2 μm.

[0034] Axial-Direction Thickening Processing 107

Normal pattern 1300 within region R is thickened by δ within region R, in the axial direction. The results are shown in Figure 14. Normal patterns 1300-1 to 1300-4 within region R become region R patterns 2600-1 to 2600-4 for M2. M2 region S patterns 2700-1 and 2700-2 also are shown in this figure. δ has the same significance as in width-direction thickening processing 106, and it has the same value.

[0035] Shifter Pattern Generation Processing 108

The shifter pattern is generated by inputting the region R data and the corresponding center line segment data. If, for each region R, center line segment data 1250 are presorted in the width direction (in Figure 15, for example, from above to below in the y-direction), it only is necessary to sequentially fetch center line segment data 1250 and assign them to shifter-less regions and shifter regions. Figure 15 [shows] the assignment results.

Fine Pattern Protection Processing 109

Fine pattern protection pattern 2500 for M2 is created by thickening by ε, in the width direction, center segment data 1250. The embodiment is shown in Figure 16. ε may be equal to the value δ, which takes into consideration the inter-mask alignment and is

used in width-direction thickening processing 106. However, to increase the dimensional accuracy by completely shading the fine pattern forming the gate electrode, $\varepsilon > \delta$ is assumed. For example the value 0.3 μm is used[3].

[0036]

By implementing the aforementioned nine types of computational processing, the patterns for M1 and M2 can be generated automatically. As shown in Figure 3, M1 is formed by using shifter patterns 1500-1 and 1500-2, region S protection pattern 1700, and region R normal patterns 1600-1 to 1600-4. As shown in Figure 4, M2 is formed by using fine pattern protection patterns 2500-1 to 2500-4, region R patterns 2600-1 to 2600-4, and region S patterns 2700-1 and 2700-2.

[0037]

The overlapping of two masks without error is shown in Figure 5. When a positive-type resist, in which light-exposed parts are dissolved by development, is used, the product set part of the latent image region 10 formed by M1 and region 12 protected by the shield part of M2 is unexposed, so the pattern is formed. It is evident that the pattern of Figure 2 is formed. The case of a transfer with M2 shifted to the lower left, relative to M1, is shown in Figure 6. Although the relative positions, etc., of the fine pattern and the normal pattern are misaligned, there is no fatal defect in the pattern shape. In the gate pattern, the superposition accuracy [relative to] another layer (e.g., the contact hole layer) becomes a problem. In this regard, however, there is no significant difference between the usual technique that uses one mask and the technique of the present invention.

[0038]

Assuming a gate layer pattern that uses the standard-cell design method, the three prerequisite restrictions mentioned in the Means of Solving the Problems will be explained supplementarily. Regarding prerequisite 1, [which states that] all fine patterns are parallel to the x-axis, all may also be parallel to the y-axis. Furthermore, if there are

[3] Translator's note: The original Japanese actually reads "03. μm". Presumably "0.3 μm" is intended.

multiple first regions for which a phase is specified, all fine patterns contained in the region may be parallel to either the x-axis or y-axis.

[0039]

Condition 2, [which states that] the spacing of the center line part of a fine pattern is p or an integral multiple of p, may be considered satisfied in the standard-cell method. Regarding the third condition for the fine pattern line width, if the shifter edge method explained in Figure 18 is applied, line width restriction is eliminated. Also, the line width need not be limited to one type, if it is taken into consideration that there may be multiple types of pattern width in fine pattern extraction processing 101, in the determination of the shield width required in fine pattern formation (e.g., at shifter edges) and its pattern generation processing, and in M2 fine pattern protection processing 109. Actually, for a CMOS gate pattern, the gate pattern width differs in p-type MOS transistors and n-type MOS transistors. However, this can be dealt with easily.

[0040]

Consequently, the technique of the present invention is applicable to the formation of gate layer patterns that use the standard-cell design method. Furthermore, it is highly applicable to pattern formation, such as when fine patterns are aligned with equal spacing.

[0041]

[Effects of the Invention]

The invention of the present application has the configuration described previously, so it has the effect described hereafter. By dividing the exposure region into the fine-pattern region that is required by the phase shifter and a region that is not, the region that forms a fine pattern and the other regions are separated, thereby enabling the independent formation of patterns in the respective regions, which enables the automatic generation of the patterns within the respective regions containing shifters, from the provided patterns to be formed.

[0042]

Also, by separating and thickening, in the up and down directions in mask M1 and in the left and right directions in mask M2, the normal pattern in regions that require a phase shifter, the shift effect can be minimized so that, even if M2 is shifted with respect to M1 before transfer, the formed pattern shape will not have constrictions or projections, so a pattern that almost faithfully reflects the design pattern can be formed.

[Brief Explanation of the Drawings]

[Figure 1]

Processing flow that automatically generates, from the provided mask pattern, the pattern for a phase-shift mask containing the phase-shift film pattern.

[Figure 2]

Pattern to be formed.

[Figure 3]

Planar layout drawing of the first mask for forming the pattern of Figure 2, when the present invention is implemented.

[Figure 4]

Planar layout drawing of the second mask for forming the pattern of Figure 2, when the present invention is implemented.

[Figure 5]

Explanation of the pattern after the two masks of Figures 3 and 4 are overlapped and transferred without shifting.

[Figure 6]

Explanation of the pattern after the mask of Figure 4 is transferred after shifting to the lower left, relative to the mask of Figure 3.

[Figure 7]

Explanation of fine pattern extraction processing 101.

[Figure 8]

Explanation of fine pattern extraction processing 101.

[Figure 9]

Explanation of the fine pattern's center line segment extraction processing 102.

[Figure 10]

Explanation of region R and region S determination processing 103.

[Figure 11]

Explanation of region R and region S determination processing 103.

[Figure 12]

Explanation of image pattern extraction processing 104 without region R and explanation of image pattern extraction processing 105 without region R.

[Figure 13]

Explanation of width-direction thickening processing 106 for a normal pattern that lacks region R.

[Figure 14]

Explanation of axial-direction thickening processing 107 for a normal pattern that lacks region R.

[Figure 15]

Explanation of shifter pattern generation[4] processing 108.

[Figure 16]

Explanation of fine pattern protection processing.

[Figure 17]

Explanation of the phase-shifting method that utilizes the edge of phase-shift film.

(a) Cross-section of phase-shift mask
(b) Complex amplitude of light that passed through the mask of (a)
(c) Intensity distribution of light that passed through the mask of (a)
(d) Cross-section of phase-shift mask for forming, with period pde, a fine pattern that utilizes the edges of the phase-shift film

[Figure 18]

Explanation of the technique for controlling the pattern width in fine pattern formation utilizing phase-shift film edges. (a) is a cross-section of a mask with a shield[5] inserted at the edge of the phase-shift film. (b) is the top view of the mask after the phase-shift film's edge was subjected to repetitive fine folding to create the shape.

[Figure 19]

Example of an unnecessary pattern that is formed when using phase-shift film.

[Figure 20]

Explanation of the technique for removing the unnecessary pattern shown in Figure 19 by using two masks.

---

[4] Translator's note: The Japanese has a typo here resulting in an incorrect character having the same sound as the intended character, but a nonsensical meaning.
[5] Translator's note: The Japanese text has a typo for "shield."

[Figure 21]

Explanation of the adverse effect on the formed pattern when there is a shift in the alignment of two masks.

[Figure 22]

Pattern to be formed in the explanation of the extension of the region by just distance α in the axial direction of the fine pattern, when determining region R, in order to deal with inter-mask misalignment.

[Figure 23]

Example of the formation of region R in the explanation of the extension of the region by just distance α in the axial direction of the fine pattern, when determining region R, in order to deal with inter-mask misalignment.

[Figure 24]

Example of the formation, in a rectangular shape, of region R in the explanation of the extension of the region by just distance α in the axial direction of the fine pattern, when determining region R, in order to deal with inter-mask misalignment.

[Figure 25]

Example of expanded region R in the explanation of the extension of the region by just distance α in the axial direction of the fine pattern, when determining region R, in order to deal with inter-mask misalignment.

[Figure 26]

Example of the pattern of a mask in which a shifter was provided, in the case where inter-mask misalignment was not dealt with.

[Figure 27]

Example of the pattern of a mask in which a shifter was not provided, in the case where inter-mask misalignment was not dealt with.

[Figure 28]

Example of pattern formation after inter-mask misalignment, when the masks of Figures 27 and 28 were used.

[Figure 29]

Example of pattern formation after mask misalignment, after the region was expanded by distance α, when determining region R.

[Figure 30]

Explanation of the case where misalignment occurred when inter-mask misalignment was not dealt with adequately.

(a) pattern to be formed, (b) top view of mask, (c) top view of mask, (d) pattern formed after misalignment.

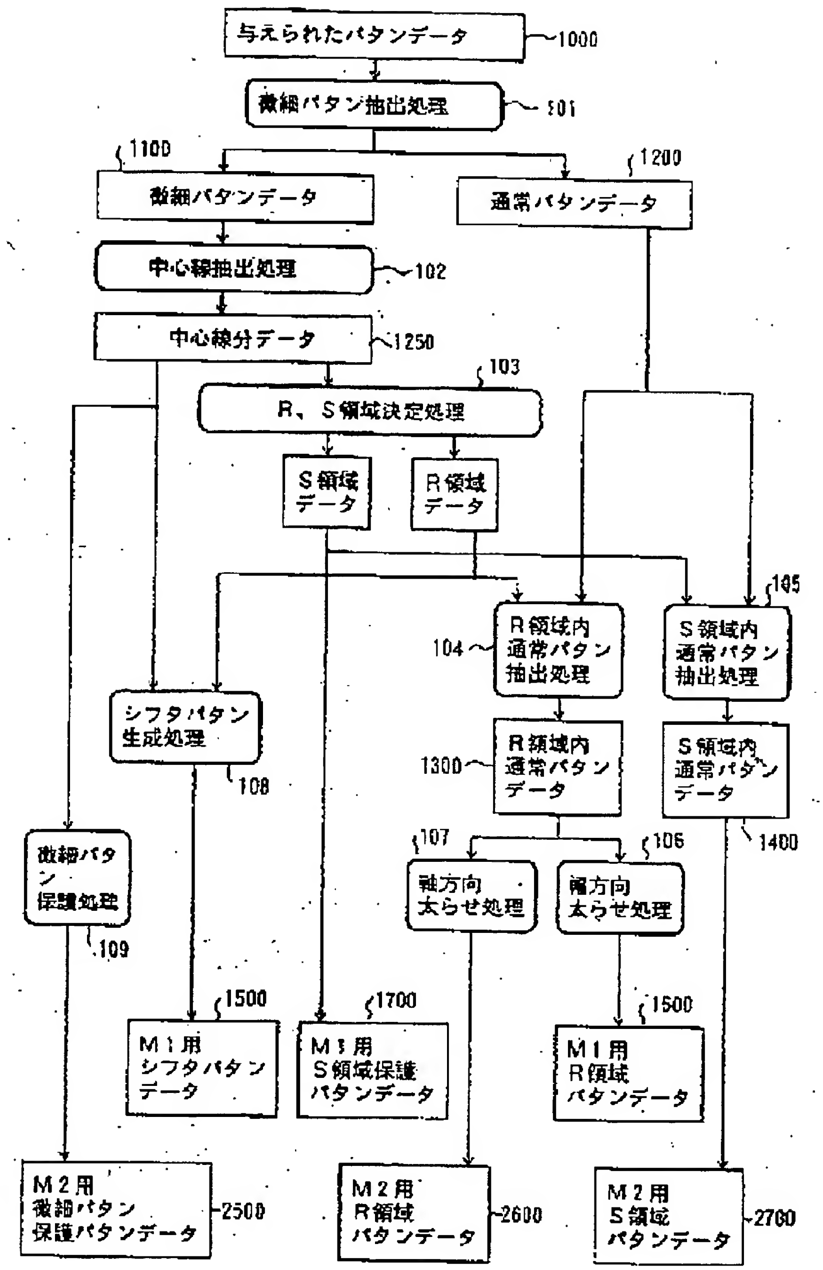
[Figure 31]

Illustrations of responses to mask misalignment by means of the present invention:

(a) Top view of mask 1 pattern
(b) Top view of mask 2 pattern
(c) Formed pattern when there is no misalignment
(d) Pattern formed after transferring with M2 shifted to the top right, relative to M1.
(e) Pattern formed after transferring with M2 shifted to the bottom left, relative to M1.

[Figure 1]

【図1】

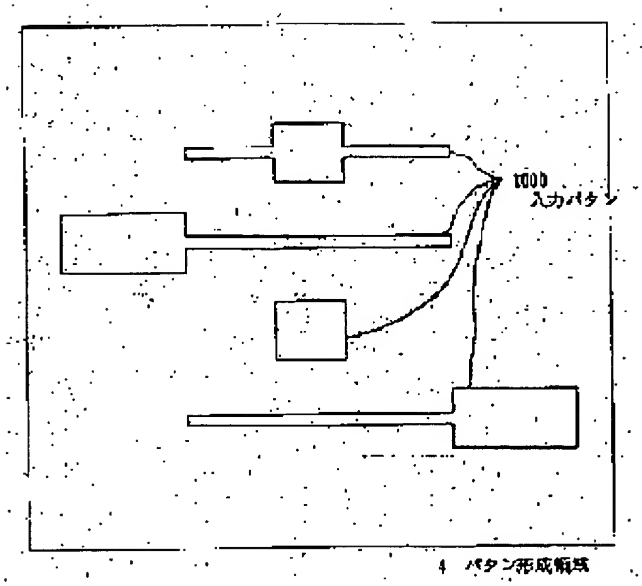

与えられたパタンデータ
1000
微細パタン抽出処理
101
1100
微細パタンデータ
1200
通常パタンデータ
中心線抽出処理
102
中心線分データ
1250
103
R、S領域決定処理
S領域データ
R領域データ
105
104
R領域内通常パタン抽出処理
S領域内通常パタン抽出処理
シフタパタン生成処理
108
1300
R領域内通常パタンデータ
S領域内通常パタンデータ
1400
107
106
微細パタン保護処理
109
縦方向太らせ処理
幅方向太らせ処理
1500
1700
1500
M1用シフタパタンデータ
M1用S領域保護パタンデータ
M1用R領域パタンデータ
M2用微細パタン保護パタンデータ
2500
M2用R領域パタンデータ
2600
M2用S領域パタンデータ
2700

Key to Fig. 1

101	Fine pattern extraction processing
102	Center line extraction processing
103	Regions R, S determination processing
	Region S data [below 103, left]
	Region R data [below 103, right]
104	Region R normal pattern extraction processing
105	Region S normal pattern extraction processing
106	Width-direction thickening processing
107	Axial-direction thickening processing
108	Shifter pattern generation processing
109	Fine pattern protection processing
1000	Provided pattern data
1100	Fine pattern data
1200	Normal pattern data
1250	Center line segment data
1300	Region R normal pattern data
1400	Region S normal pattern data
1500	M1 shifter pattern data
1600	M1 region R pattern data
1700	M1 region S protection pattern data
2500	M2 fine pattern protection pattern data
2600	M2 region R pattern data
2700	M2 region S pattern data

[Figure 2]

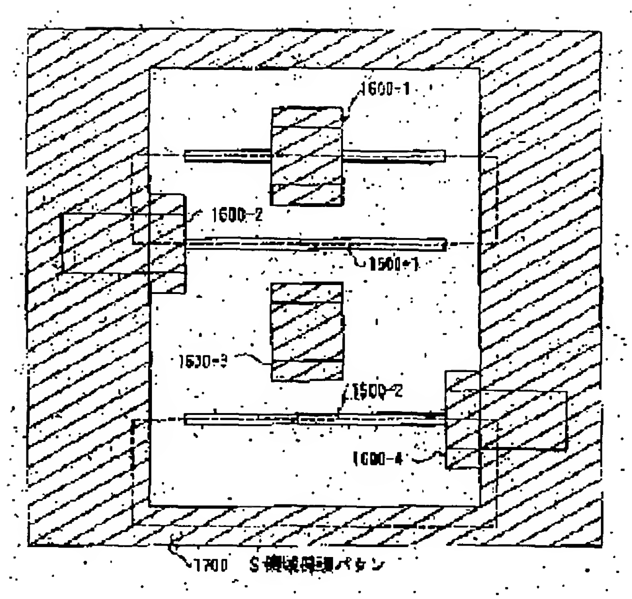
【図2】



Key

4	Pattern formation region
1000	Input pattern

[Figure 3]

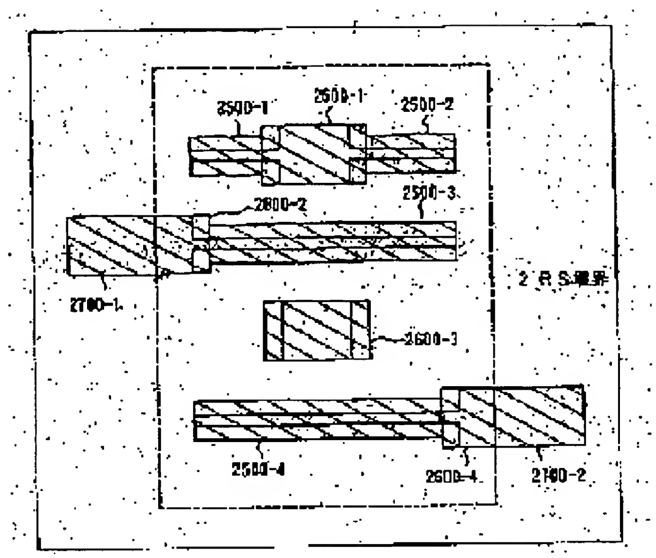


Key

1700 Region S protection pattern

[Figure 4]

【図4】

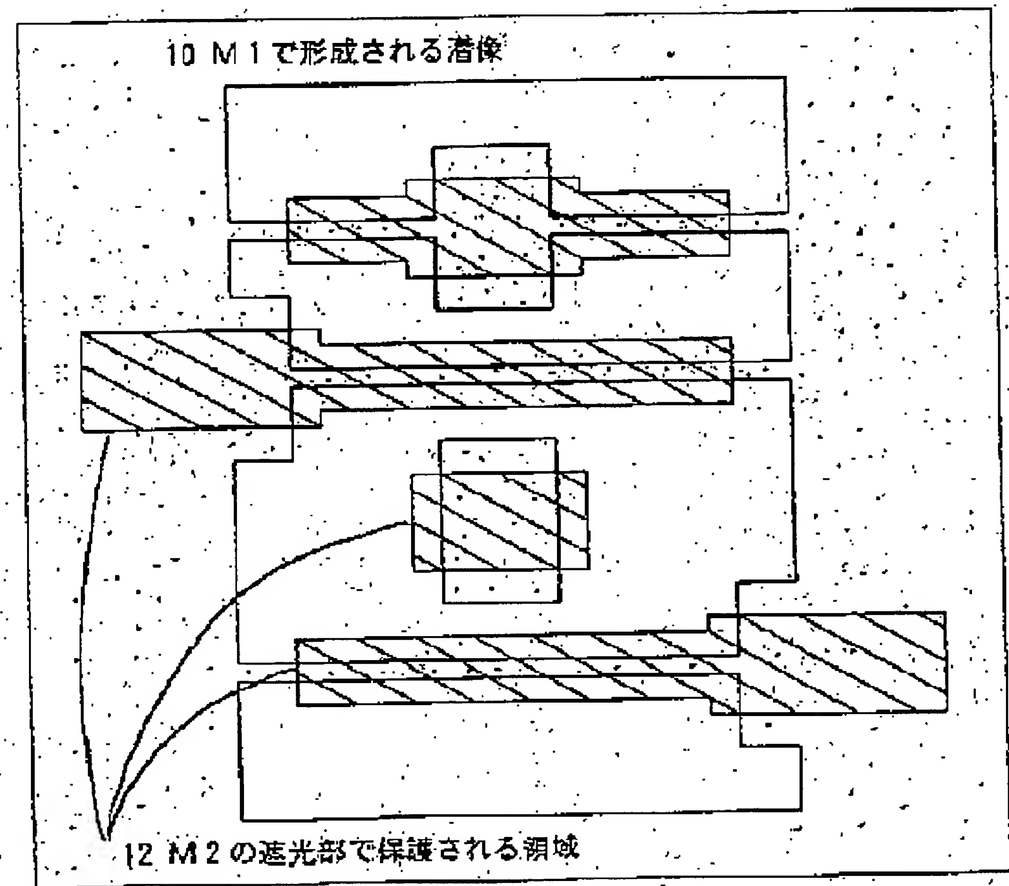


Key

2 R-S boundary

[Figure 5]

[図5]



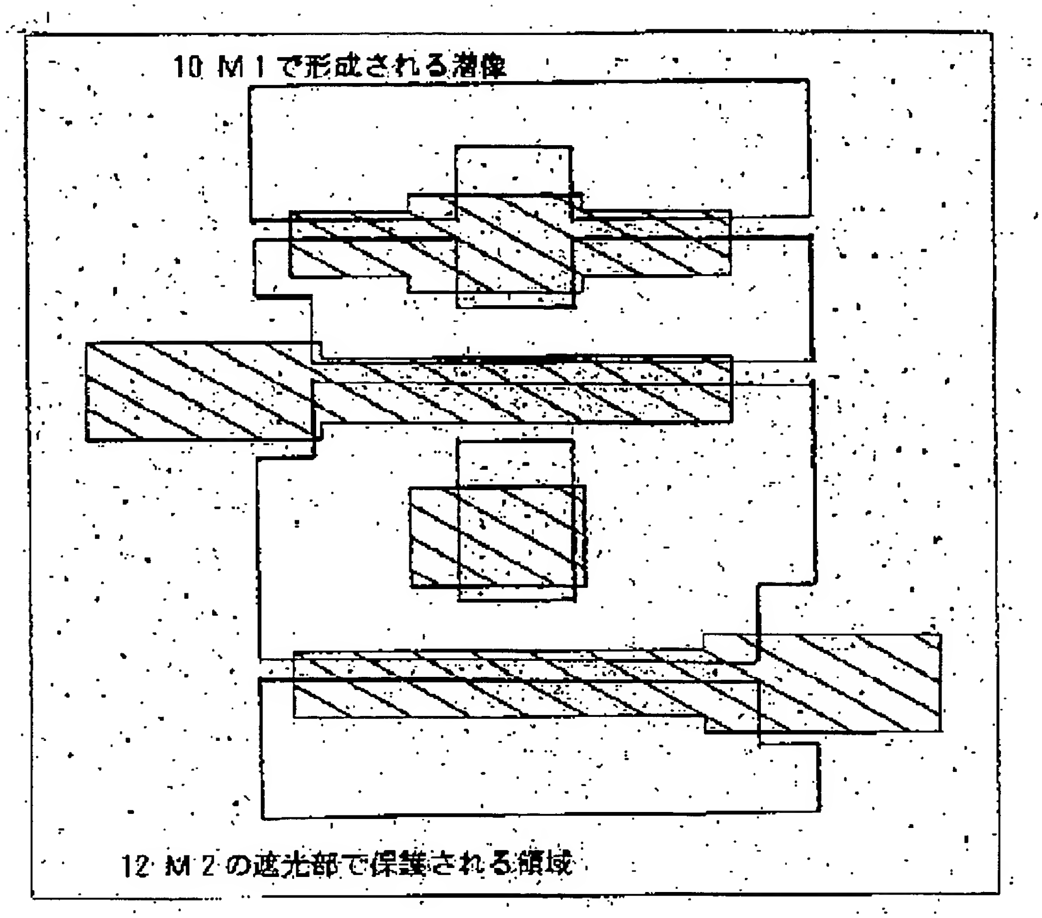
Key

10 Latent image formed by M1

12 Region protected by M2 shield part

[Figure 6]

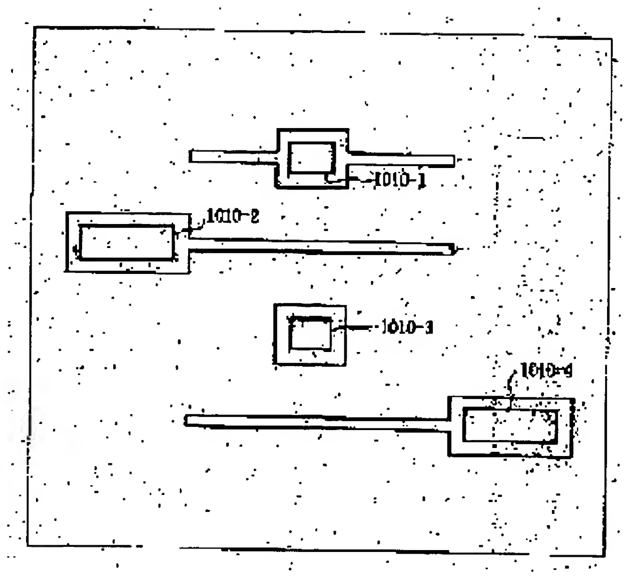
【図6】



Key
10 Latent image formed by M1
12 Region protected by M2 shield part

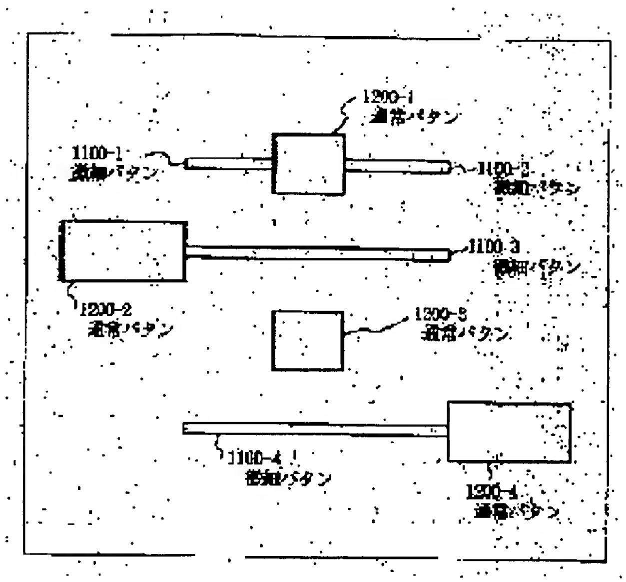
[Figure 7]

【図7】



[Figure 8]

【図8】



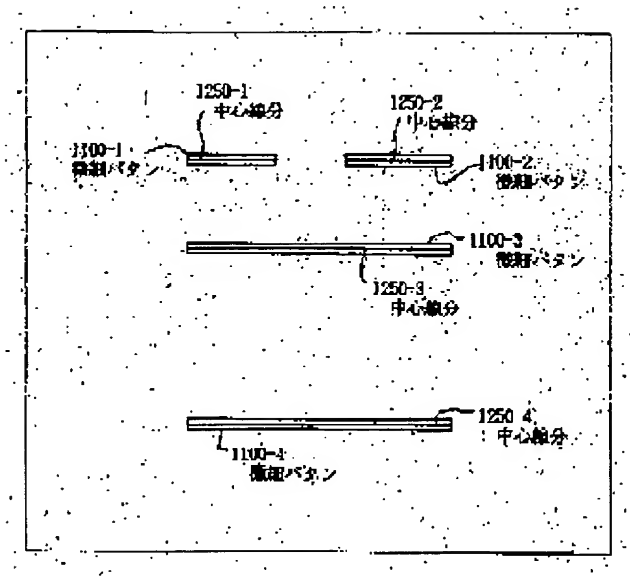
<u>Key</u>

1100-1 to -4 Fine pattern

1200-1 to -4 Normal pattern

[Figure 9]

【図9】



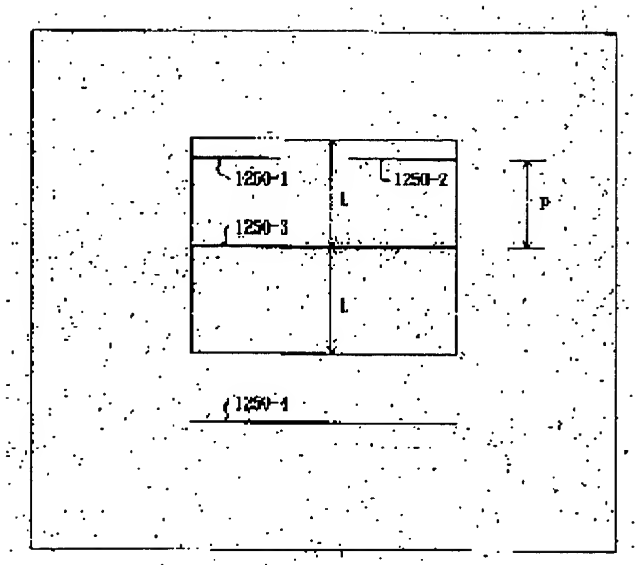
Key

1100-1 to -4 Fine pattern

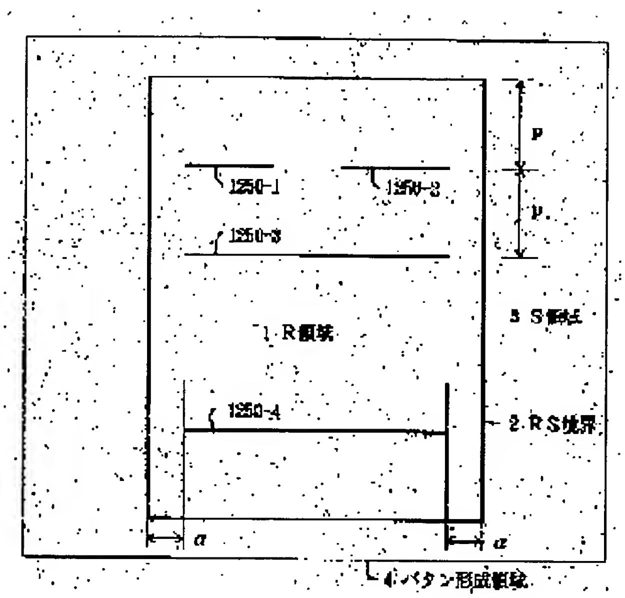
1250-1 to -4 Center line segment

[Figure 10]

【図１０】



[Figure 11]



Key

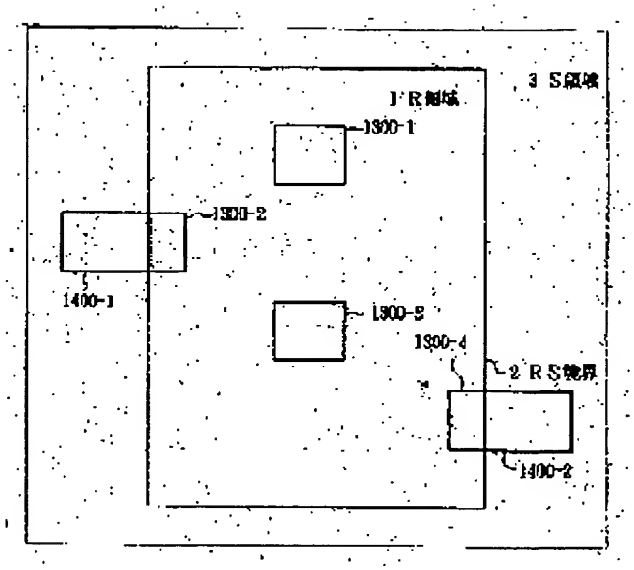
1 Region R

2 R-S boundary

3 Region S

[Figure 12]

【図１２】



Key

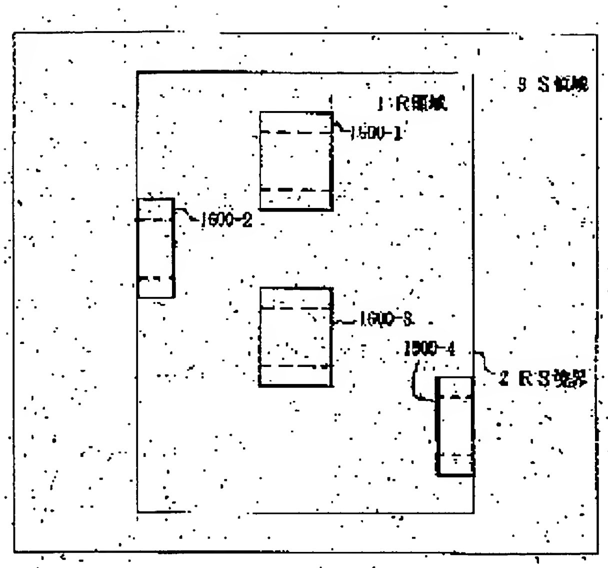
1 Region R

2 R-S boundary

3 Region S

[Figure 13]

【図１３】



Key

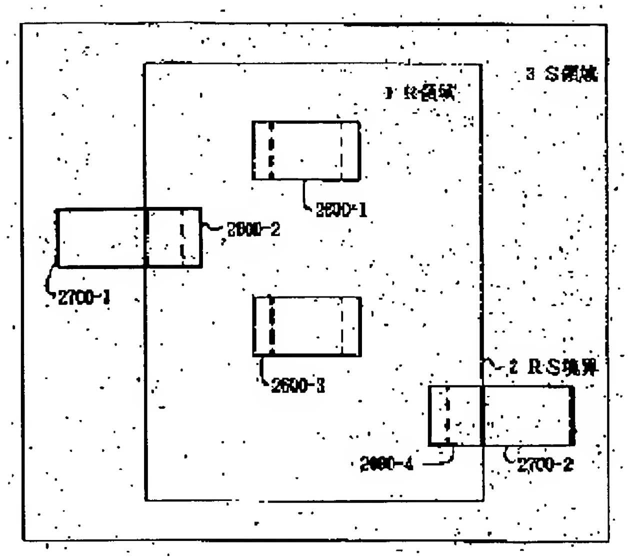
1 Region R

2 R-S boundary

3 Region S

[Figure 14]

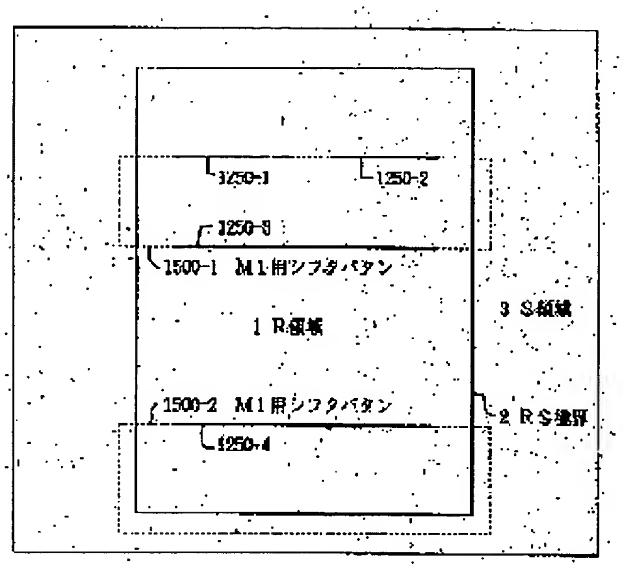
【図１４】



<u>Key</u>
1 Region R
2 R-S boundary
3 Region S

[Figure 15]

【図１５】

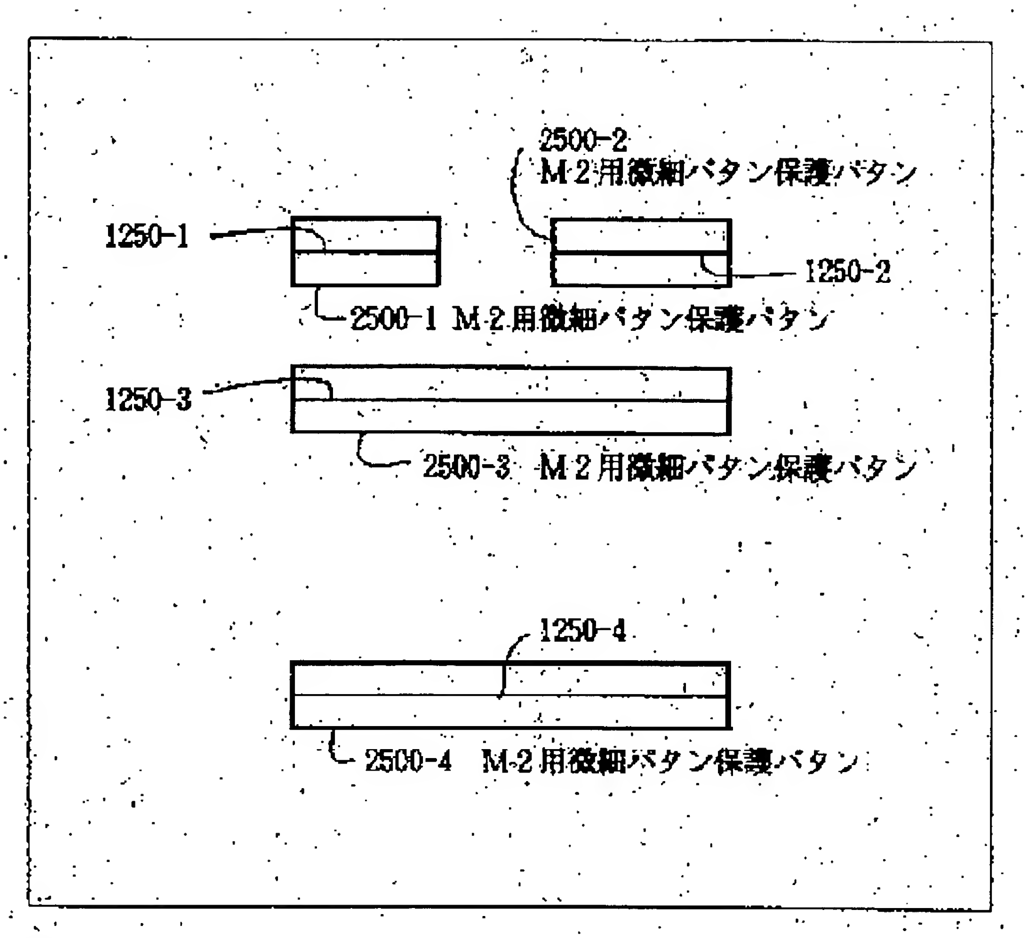


<u>Key</u>

1	Region R
2	R-S boundary
3	Region S
1500-1, -2	M1 shifter pattern

[Figure 16]

【図16】

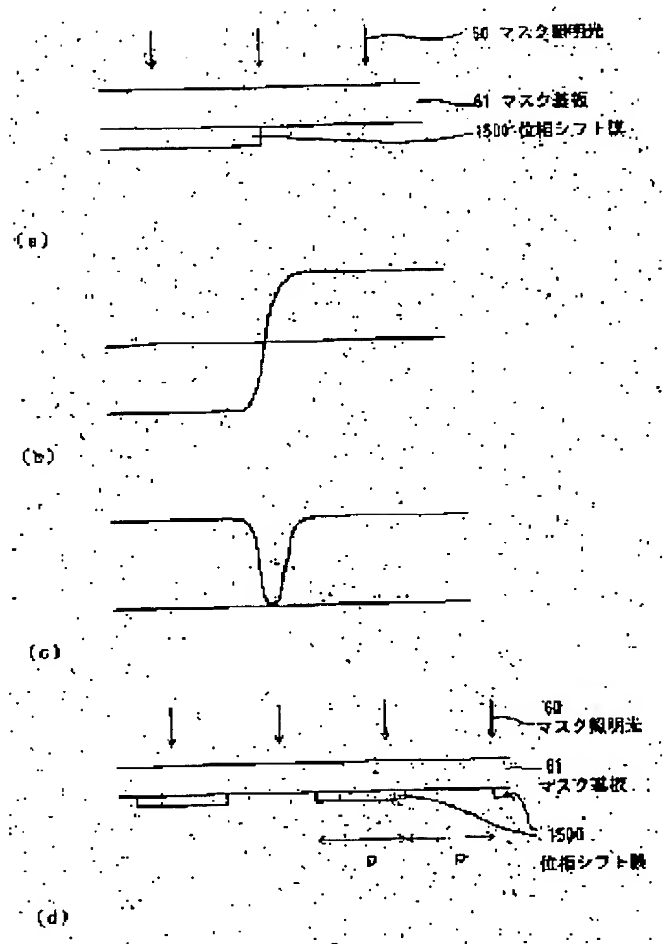


Key

2500-1 to -4 M2 fine pattern protection pattern

[Figure 17]

【図17】

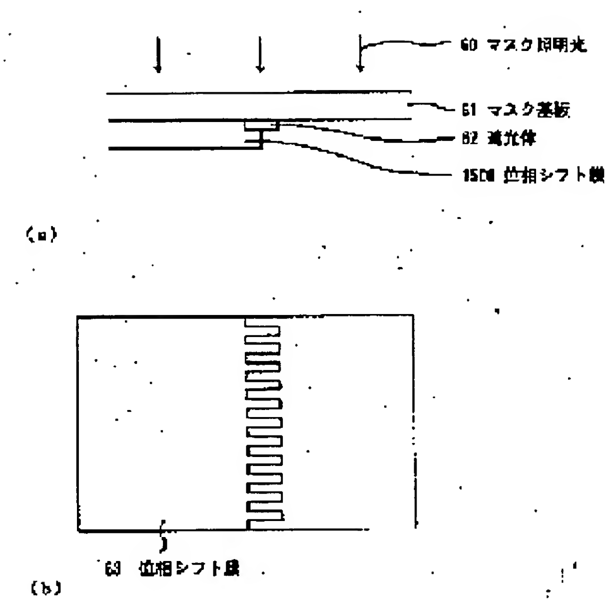


Key

60	Mask illumination light
61	Mask substrate
1500	Phase-shift film

[Figure 18]

【図１８】

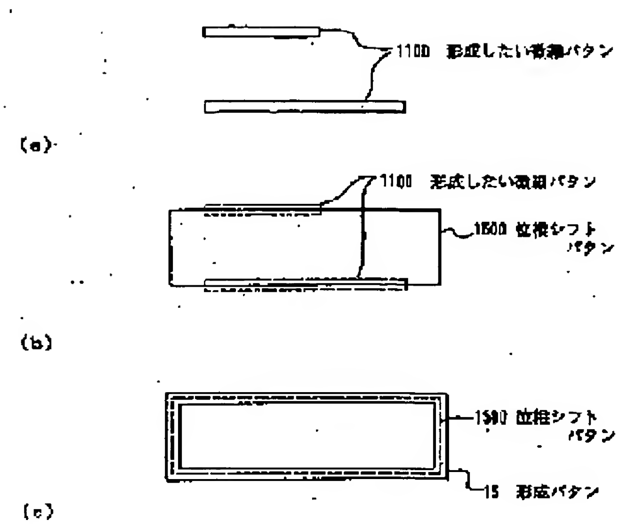


Key

60	Mask illumination light
61	Mask substrate
62	Shield
63	Phase-shift film
1500	Phase-shift film

[Figure 19]

【図１９】



Key

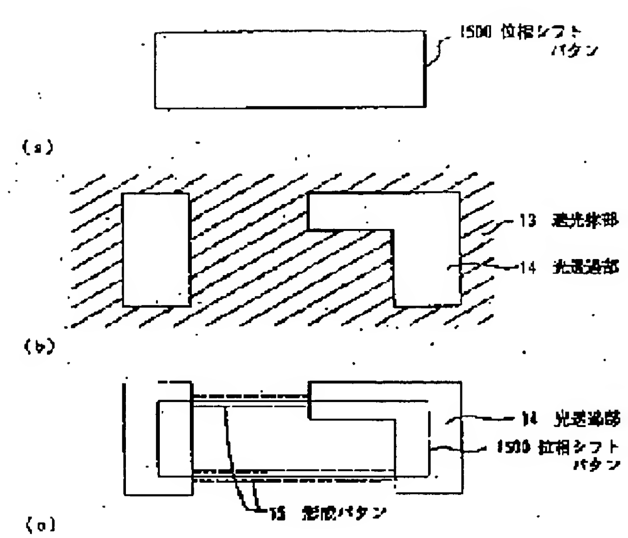
15 Formed pattern

1100 Fine pattern to be formed

1500 Phase-shift pattern

[Figure 20]

【図２０】



Key

13 Shield part

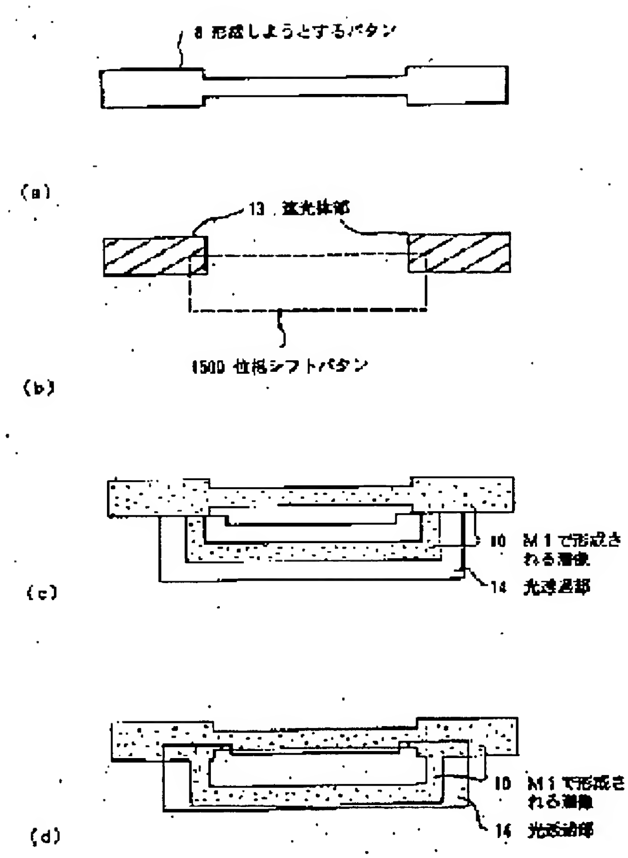
14 Phototransmissive part

15 Formed pattern

1500 Phase-shift pattern

[Figure 21]

【図２１】

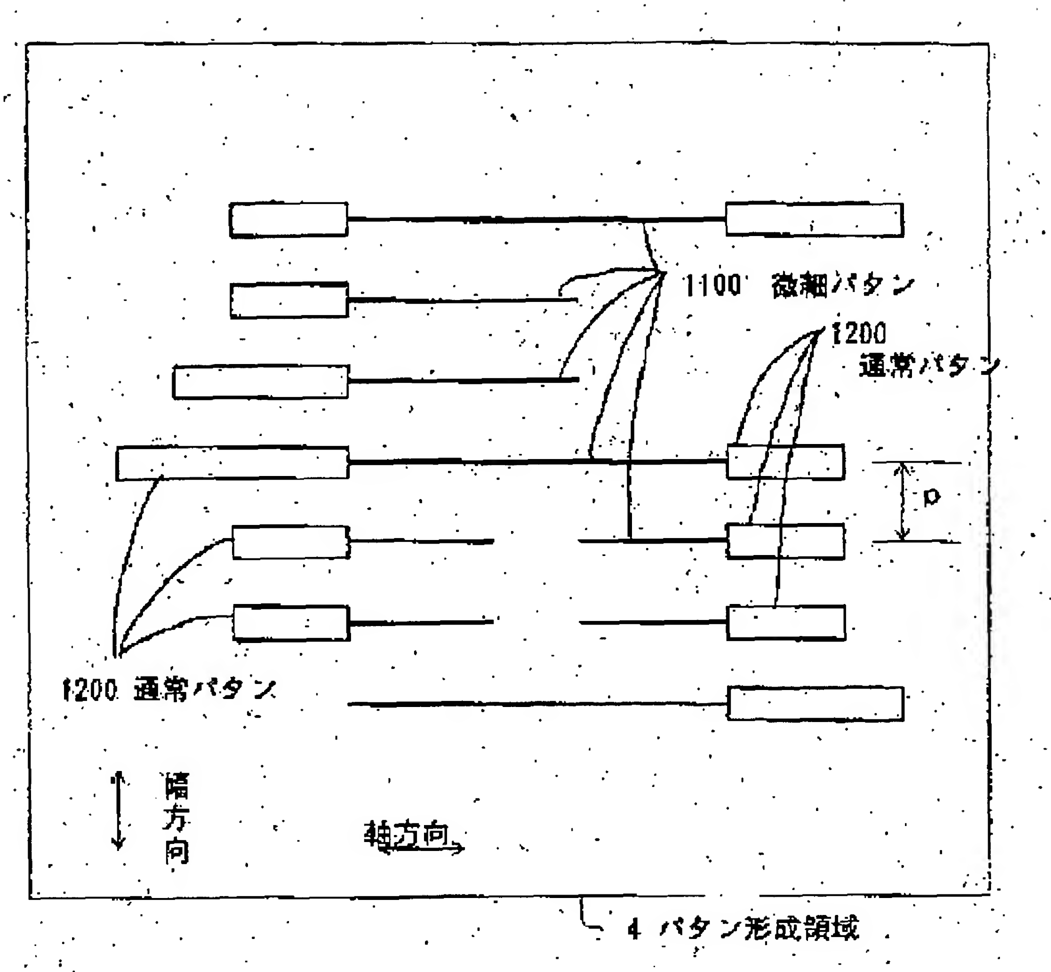


Key

8	Pattern to be formed
10	Latent image formed by M1
13	Shield parts
14	Phototransmissive part
1500	Phase-shift pattern

[Figure 22]

【図２２】



Key

4 Pattern formation region

1100 Fine pattern

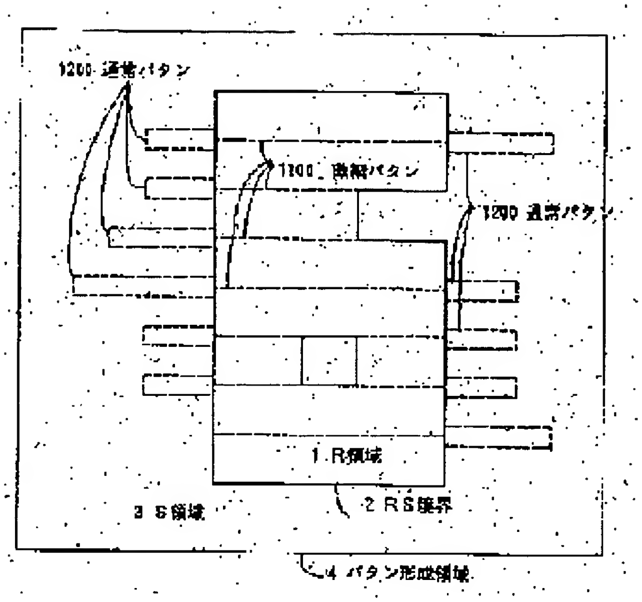
1200 Normal pattern

↕ Width direction

↔ Axial direction

[Figure 23]

【図2 3】

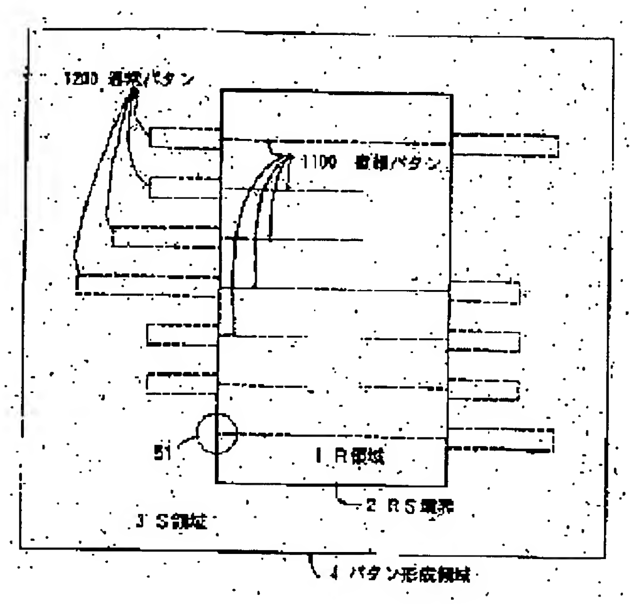


Key

1	Region R
2	R-S boundary
3	Region S
4	Pattern formation region
1100	Fine pattern
1200	Normal pattern

[Figure 24]

【図２４】

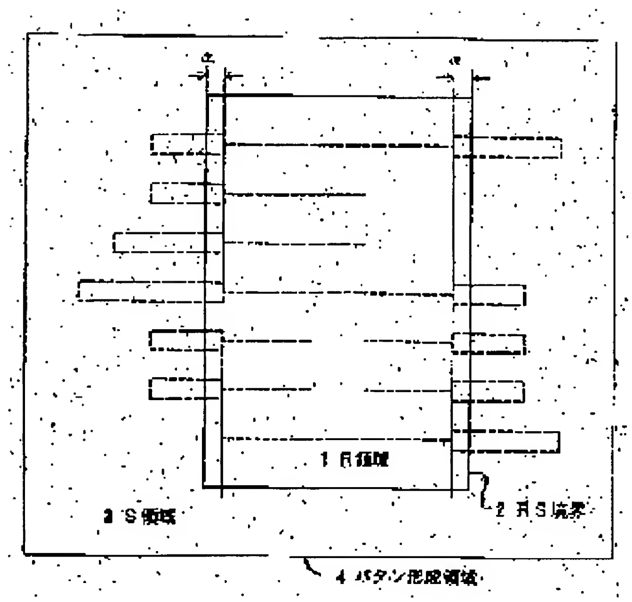


Key

1	Region R
2	R-S boundary
3	Region S
4	Pattern formation region
1100	Fine pattern
1200	Normal pattern

[Figure 25]

【図２５】



Key

1 Region R

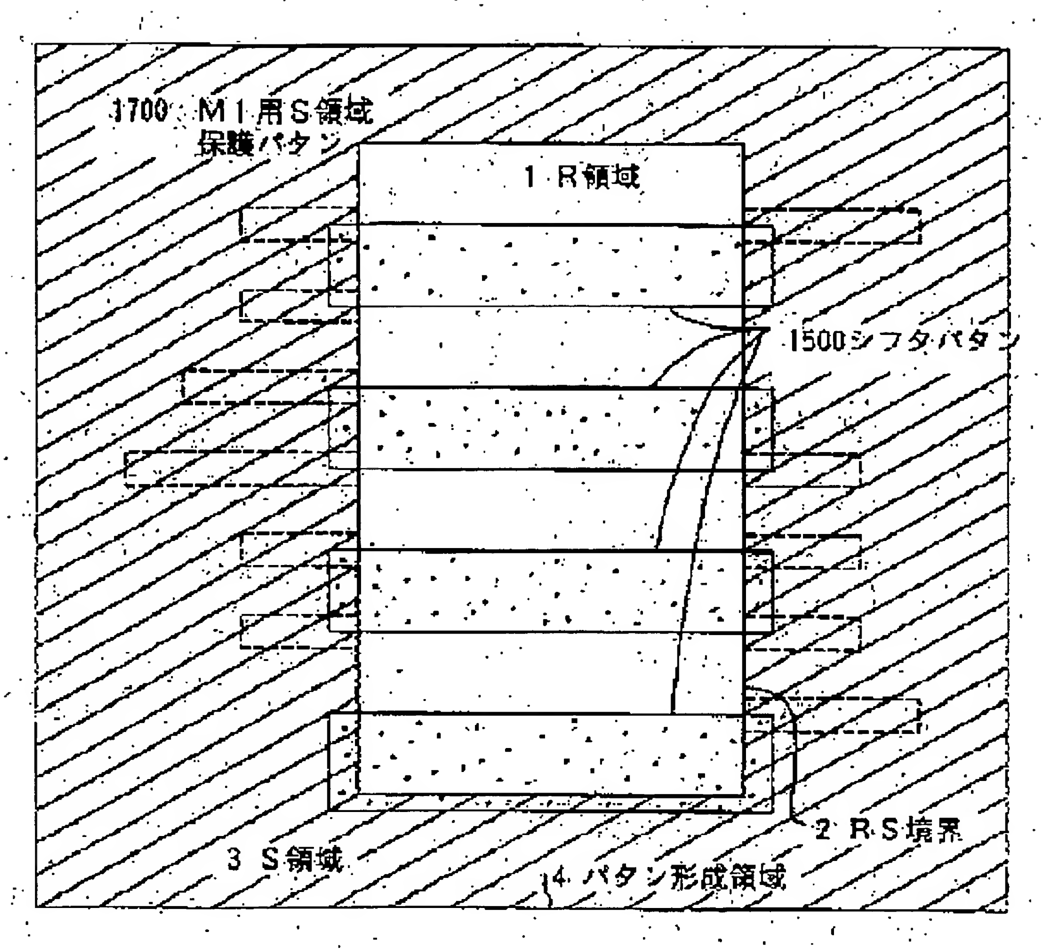
2 R-S boundary

3 Region S

4 Pattern formation region

[Figure 26]

【図２６】

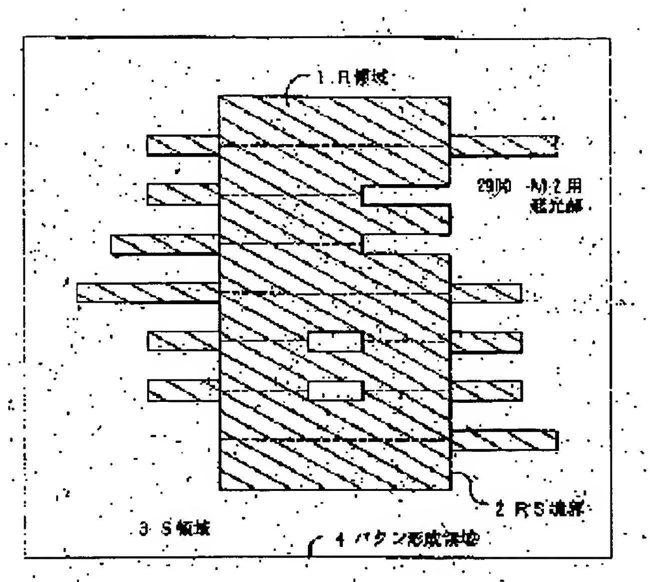


Key

1	Region R
2	R-S boundary
3	Region S
4	Pattern formation region
1500	Shift pattern
1700	M1 region S protection pattern

[Figure 27]

【図２７】



Key

1 Region R

2 R-S boundary

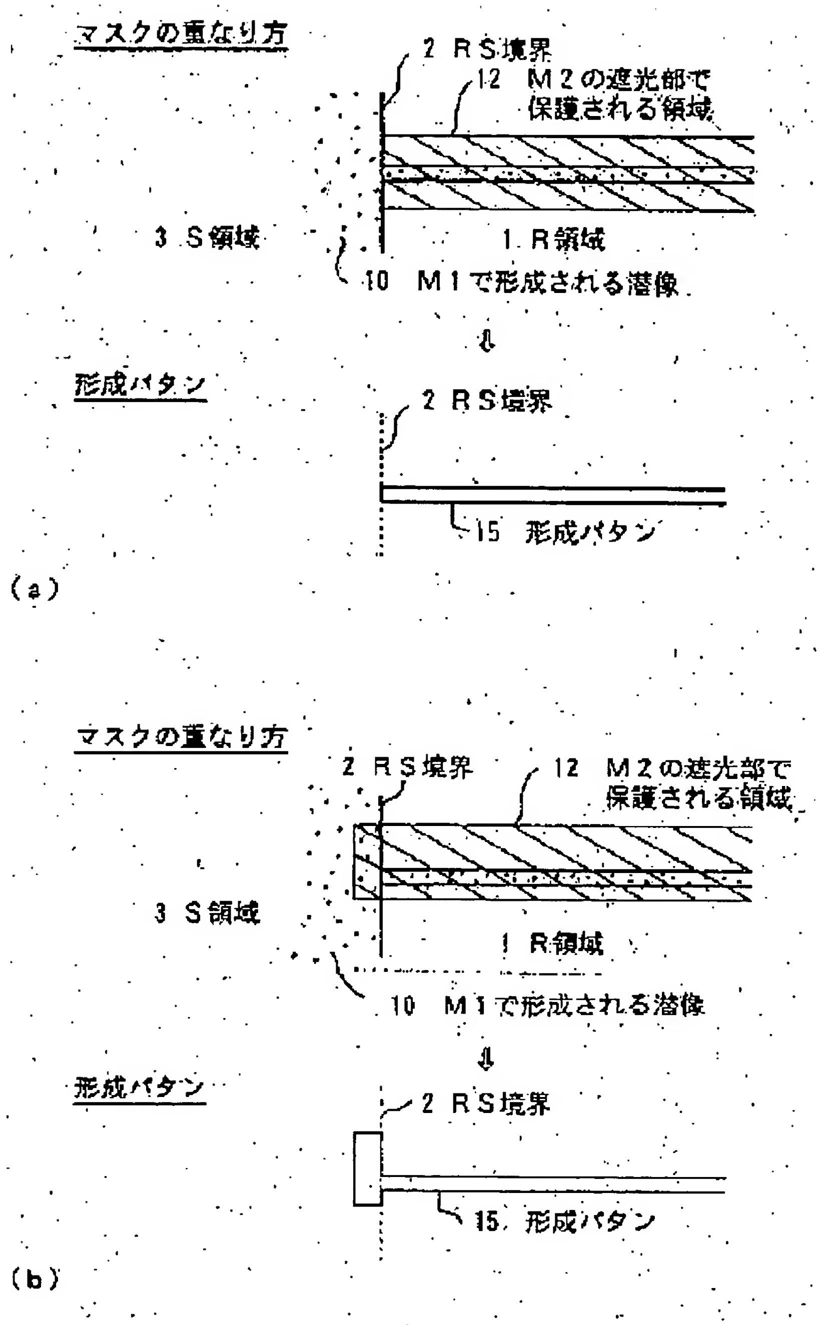
3 Region S

4 Pattern formation region

2900 M2 shield part

[Figure 28]

【図２８】



Key to Figure 28

(a) & (b)

Mask superposition method

1 Region R

2 R-S boundary

3 Region S

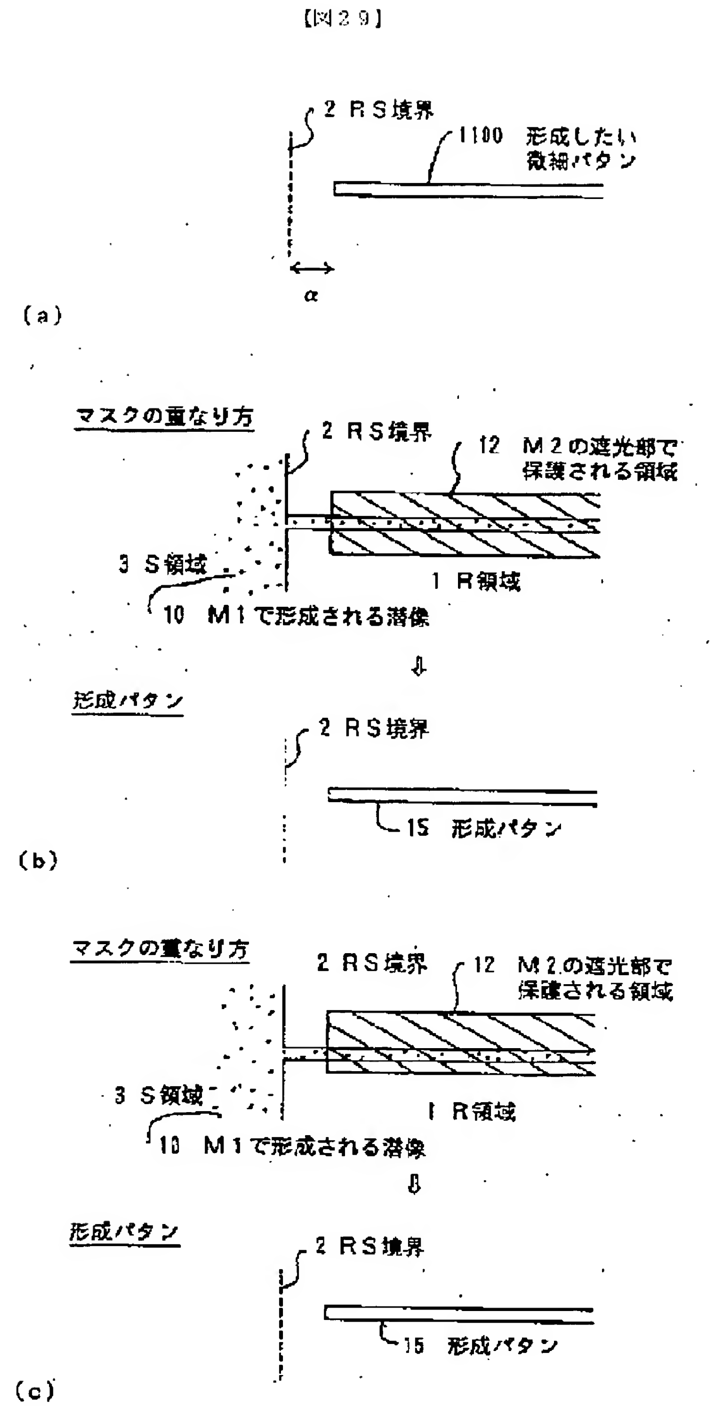
10 Latent image formed by M1

12 Region protected by M2 shield part

Formed Pattern

15 Formed pattern

[Figure 29]


【図２９】
２ＲＳ境界
1100 形成したい微細パタン
α
(a)
マスクの重なり方
２ＲＳ境界
12 Ｍ２の遮光部で保護される領域
３Ｓ領域
１Ｒ領域
10 Ｍ１で形成される潜像
形成パタン
２ＲＳ境界
15 形成パタン
(b)
マスクの重なり方
２ＲＳ境界
12 Ｍ２の遮光部で保護される領域
３Ｓ領域
１Ｒ領域
10 Ｍ１で形成される潜像
形成パタン
２ＲＳ境界
15 形成パタン
(c)

Key to Figure 29

(a)

2 R-S boundary

1100 Fine pattern to be formed

(b) & (c)

Mask superposition method

1 Region R

3 Region S

10 Latent image formed by M1

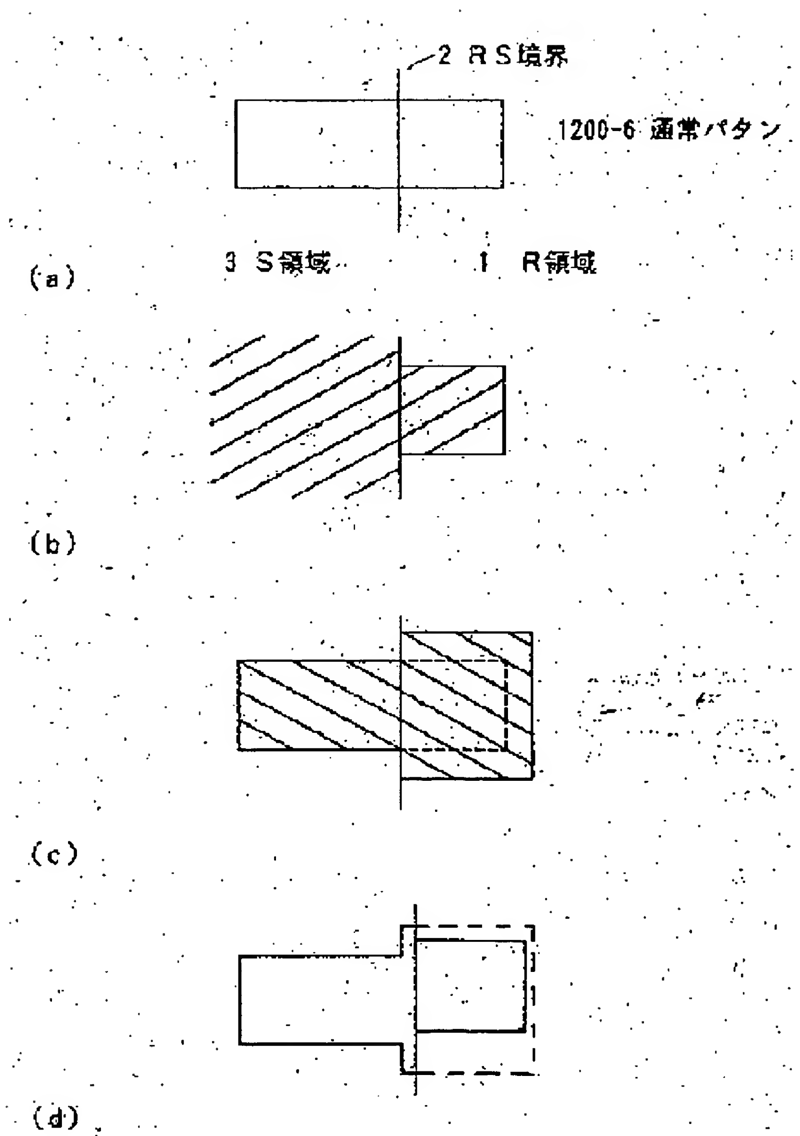
12 Region protected by M2 shield part

Formed Pattern

15 Formed pattern

[Figure 30]

【図３０】

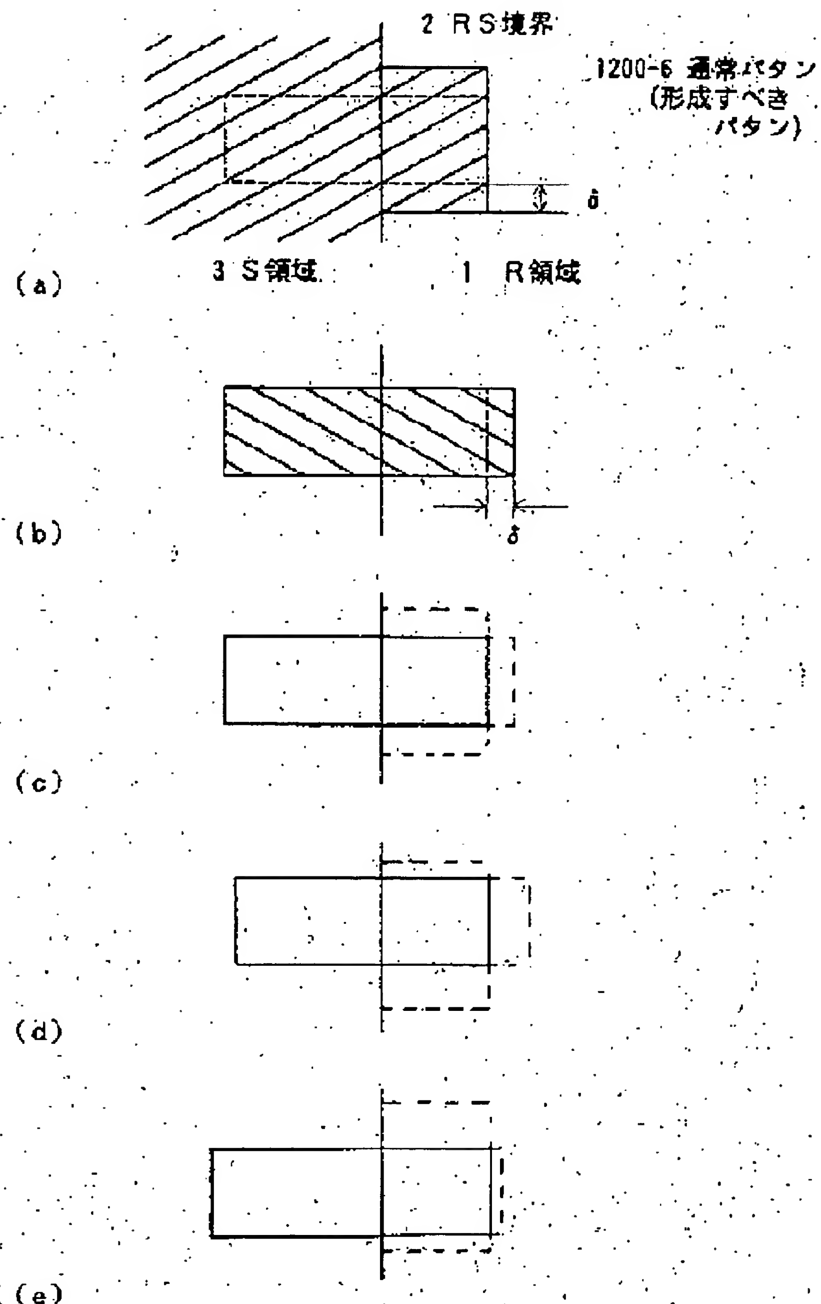


Key

1	Region R
2	R-S boundary
3	Region S
1200-6	Normal pattern

[Figure 31]

【図３１】



Key

1	Region R
2	R-S boundary
3	Region S
1200-6	Normal pattern (pattern to be formed)

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Title of the Invention: Photo-mask and Mask Pattern Data Processing Method

Application No.: Hei4-70786

Filing Date: March 27, 1992

Assignee: Nippon Telegraph and Telephone Corp.

SPECIFICATION

[Title of the Invention]

PHOTO-MASK AND MASK PATTERN DATA PROCESSING METHOD

[Abstract]

[Object]

There is provided mask patterns enables to be easily and automatically generated, and further to reduce the effect of a positioning shift in a plurality of masks, in a multistage imprinting method.

[Structure]

In a pattern forming by exposure using a mask M1 including a phase shift pattern 1500, and a plurality times of exposure including exposure for eliminating unnecessary patterns caused thereby, a phase shifter divides a exposure area into an area having a necessary fine pattern 1100 and the other area 3 (103), one mask provides a shifter, and comprises a mask shifter pattern having an edge corresponding to the fine pattern and a pattern corresponding to the other pattern 1600 in an area 1, and an area 3 is a shading mask pattern, the other mask without a shifter is automatically generated to have a normal pattern forming a pattern 2600 existing in the area 3, and a pattern for eliminating unnecessary patterns in the shifter forming area. Further, one mask fattens the mask pattern in one axial direction, and the other mask fattens the mask in the orthogonal direction.

[Claims]

1. In a pattern forming for forming a pattern of one layer by exposure using a mask including a pattern, which shifts a phase difference of light passing both sides of a fine pattern to be formed to become approximately π, and a plurality times of exposure including exposure for eliminating unnecessary patterns caused thereby, a mask pattern data processing method comprising;

firstly setting a first area necessary for passing a light having a phase difference for forming said fine pattern, and secondly separating all patterns or all patterns except said fine pattern into outside and inside of said first area.

2. A mask pattern data processing method as claimed in claim 1, wherein the step of setting a first area comprising setting a boundary of said first area such that the length of a fine pattern, which is formed in that, a phase difference of light passing both sides becomes π, is longer than the length of a fine line finally formed, by the distance corresponding to a overlapping error, caused by each overlapping of at least a plurality of masks, in the both sides of axial direction of a fine pattern.

3. In a photo-mask for forming a pattern of one layer by exposure using a mask including a pattern, which shifts a phase difference of light passing both sides of a fine pattern to be formed to become approximately π, and a plurality times of exposure including exposure for eliminating unnecessary patterns caused thereby;

when a pattern which should be formed using a light with a phase difference is designated as fine pattern, and a pattern formed by imprinting a light shading body on a conventional mask, other than the fine pattern is designated as normal pattern;

and when a longitudinal direction in which a fine line is extending is designated as axial direction, and the direction perpendicular to the axial direction is designated as width direction;

said photo-mask comprising, on a pattern in a first area which is necessary f or passing a light with a phase difference to form said pattern,

a mask forming a fine pattern including a normal pattern in said first area h aving the dimensions of the pattern length formed by said plurality times of exposur e in the axial direction, and the pattern width larger than the pattern width finally fo rmed by said plurality times of exposure in the width direction by predetermined len gth; and

another mask including a normal pattern in said first area having the dimens ions of the pattern length longer than the pattern length finally formed by said plural ity times of exposure in the axial direction by predetermined length, and the pattern width finally formed by said plurality times of exposure in the width direction.

4. In a photo-mask for forming a pattern of one layer by exposure usin g a mask including a pattern, which shifts a phase difference of light passing both si des of a fine pattern to be formed to approximately π, and a plurality times of expos ure including exposure for eliminating unnecessary patterns caused thereby; said phot o-mask comprising,

a boundary of said first area set such that the length of a fine pattern formed i n that a phase difference of light passing both sides as about π, is longer than the le ngth of a fine line formed by said plurality times of exposure, in the both sides of a xial direction of a fine pattern by a predetermined distance.

[Detail Description of the Invention]

(0001)

[Field of the Invention]

The present invention relates to a method of making mask patterns and a method of forming masks and patterns for forming fine patterns such as LSI a nd the like on a wafer (substrate) using a projection lens.

(0002)

[Prior Art]

Usually, in a projection exposure technology for forming fine patterns of LSI and the like, a high resolution is required. Therefore, the projection lens for the projection exposure apparatus has the resolution of nearly theoretical limit decided by the wavelength of light. Further, a study of phase shift method has been advanced in recent years, for the method of imprinting finer patterns. In the phase shift method, the resolution may be improved by providing a transparent film on a part of light transmission part of the mask, which is positioned on the object surface of projection lens for generating a phase difference of about π in the transmission light. The phase shift method may be classified into a number of methods, however, as a method of forming an isolated fine pattern, there is a pattern forming method using the phase difference of about π, occurred at the edge of the phase shift film. This method will be explained using Fig.17. Fig. 17(a) shows a part of the cross-section of phase shift mask, 60 indicates a light illuminating the mask, 61 is a mask substrate, 1500 is a phase shift film, and there is a boundary edge (shifter edge), in which the phase shift film 1500 is present and it is absent in the figure. A complex amplitude distribution of the light passed this mask becomes as shown in Fig. 17(b) and its corresponding light intensity distribution becomes as shown in Fig. 17(c). In Figs. 17(a), (b), and (c) the abscissas are coordinated. These figures show that its corresponding light intensity becomes zero due to variation of phase by π at the edge part. As mentioned above, the edge part of phase shift film forms a very fine light shading part, therefore in case of using e.g. g-ray (wave length of 436nm) of a high voltage mercury lamp, the pattern width is limited to about 0.5 microns when a light shading pattern, which is made of such as normal chromium, is imprinted considering to a focus depth, however, a pattern of 0.2 microns may be formed when this shifter edge is used. This line width should be called as a limit resolution line width. As mentioned above, the use of the shifter edge is expected for an application to form fine patterns.

(0003)

At the time of using this shifter edge, two points of supplementary explanations will be given. One point is the limit of a pattern density. The light shad ing part of fine width may be formed using the shifter edge, for that it is necessary that a light with a phase difference needs to transmit at both sides of the light shadi ng part. This shows that there is a limit in the interval in forming two fine width lig ht shading parts adjacently. Fig. 17(d) shows the case to form 0.2 microns wide light shading parts successively with the interval of p, however, the interval of the light s hading parts is required to be almost 1 micron.

(0004)

Another point is the control of line width of the light shading parts. In order to obtain the finest line width, the use of a shifter edge with a phase differ ence of π is appropriate and at that time a line width of 2 microns is available. How ever, in actual LSI pattern forming, there is a case to be required to form lines, whic h are finer than the minimum line width (e.g. 0.5 microns) obtained by imprinting th e normal light shading body, and which are fatter than the width (e.g. 0.2 microns) obtained by the above mentioned shifter edge. A method of forming line width betw een these is shown in Fig. 18(a) and (b). Symbol (a) shows a cross-section of the ph ase shift mask. A pattern width over the limit resolution line width may be realized by inserting a light shading body made from such as chromium into the shifter edge part, and by adjusting the line width of the light shading body. Symbol (b) shows a plan structure of the phase shift mask. Patterns over the limit resolution line width are realized by providing fine folds at the edge part of phase shift film. As this, patt erns that are over the limit resolution line width may be formed, even if those are u nder the line width obtained by imprinting the normal light shading body, by using t he edge of shifter. Those pattern forming methods including Figs. (a), (b) should be called shifter edge methods herein.

(0005)

The greatest problem of the pattern forming using the shifter edge method is that fine patterns are formed in all edge parts. Fig. 19 is its explanatory d

rawing, and fine patterns 1100 to be formed are shown in (a), a phase shift mask, in cluding a phase shift pattern 1500 for forming fine patterns shown by (a) using the s hifter edge method, is shown in (b), and a pattern 15 formed by using the mask sho wn by (b) is shown in (c). It is known that unnecessary patterns are formed at the c dge parts of shifter. As methods that do not generate this unnecessary patterns, ther e are proposed a method using a multistage phase shift film and a multi-imprinting method using a plurality of masks.

(0006)

The method using a multistage phase shift film makes the both side phase differences of the parts necessary for fine pattern forming π, using a plurality of phase shift films having various phase differences, however, makes the both side phase differences of the parts unnecessary for fine pattern forming e.g. 60 degrees n ot to form patterns. This method enables to form desired patterns with one phase shi ft mask, however, it needs to make a multistage phase shift film, therefore has a fata l defect of difficulty in making the mask.

(0007)

Figs. 20 (a), (b), (c) are explanatory drawings for the multistage imp rinting method using two masks, and considers (a) of Fig. 19 to be patterns to be fo rmed. Fig. 20 (a) shows a Mask 1 with the same phase shift film as Fig. 19 (b), and Fig. 20 (b) shows a Mask 2 which is composed of only a light shading body. Fig. 20 (c) shows these two masks in overlapped state for forming patterns. If developme nt is performed after exposure using these two masks, only shaded parts by both of t he two masks are pattern-formed as the final light shading parts. The pattern as sho wn in dotted lines of Fig. 20 (c) corresponds to this. Namely, a fine pattern is forme d at the boundary edge where the phase difference of Mask 1 becomes π, and unnec essary parts are removed by Mask 2. This multistage imprinting method has an adva ntage of easy mask making, because used phase shift film is only one type to be cor responding to π by the phase difference of transmitting light.

(0008)

[Problems to be solved by the Invention]

Conventionally, as a method for removing unnecessary patterns using this multistage imprinting method, it was possible to manually position the shifter or the light shading part to each pattern, however, no method has been proposed to automatically generate/position these patterns, when complex patterns are mixed. Also, in an actual pattern forming process, when forming one layer pattern by two times of exposure using different masks, the occurrence of positioning error is inevitable between the two times of exposure. Fig. 21 shows one example of deformation of the pattern when a relative positioning shift occurred in two times of exposure. Fig. 21(a) shows a pattern 8 to be formed, Fig. 21(b) is a first mask (M1) used for that, which is composed of light shading parts 13 and a phase shift pattern 1500, Fig. 21(c) shows the state, in which a second mask (M2) is overlapped to the pattern 10 obtained as a latent image by the exposure using M1, without a positioning shift. As the latent image existing in the area corresponding to the light transmitting part 14 of M2 is removed, the objective pattern shown in (a) is formed. On the other hand, Fig. 21(d) shows the case that M2 is imprinted with a positioning shift upward relative to M1. The light transmitting part on M2 for removing unnecessary patterns formed by M1 overlaps on the latent image of the pattern to be formed, and the normal pattern parts of both sides of the fine pattern receive a deformation to lose its part, and constrictions are generated in the fine pattern parts.

(0009)

The present invention is made in view of the points mentioned above, and its object is to provide a mask pattern forming method and a mask, which receive a little effect of positioning error in a plurality of masks used, in forming circuit patterns for LSI and the like using the phase shift method, at the pattern forming of one layer using a plurality of masks, and further to provide an automatic generation method for mask patterns including shifter patterns, although imposing limitation to LSI and the like from the view point of a part of patterns.

(0010)

[Means to solve the Problems]

First the terms used here will be explained. In formed patterns, a pattern with a narrow width pattern formed by using a shifter edge is described as a fine pattern 1100, and a pattern formed by imprinting a light shading body usually existing on a mask is described as a normal pattern 1200. A pattern to be formed or a given pattern 1000 may confidently be classified into a fine pattern 1100 or a normal pattern 1200, and a pattern with a width of over 0.5 microns is classified into a normal pattern 1200, a pattern with a width of below 0.5 microns into a fine pattern 1100. The length of a fine pattern is long enough compared to its width, for instance 4 times longer, and the long extending direction should be described as an axial direction and the direction perpendicular to the axial direction should be described as a width direction. Also, for forming a fine pattern using the shifter edge method, an area is necessary for transmitting a light having a phase of separating about π in both sides of the fine pattern, and the area should be described as a phase designation area R 1 or R-area 1. An area, in which a pattern is formed, for instance a chip area and an area other than the R-area should be described as S-area 3. The whole pattern forming area 4 is composed of an R-area 1 and an S-area 3, and both areas do not overlap each other. The boundary of R-area and S-area should be described as an RS-boundary 2. These areas are shown in Figs. 22, 23, and 24. The fine pattern 1100 has originally a width, however, for simplification of the drawing, it is shown as a line segment in Fig. 22.

(0011)

First, the present invention will generally be explained. The multistage imprinting method is used, however, exposure is limited to two times of exposure using two masks herein, and a first mask (M1) is a mask with a phase shift film (shifter) and a second mask (M2) is a mask without a shifter. Namely, at the first exposure, a fine pattern is formed using the shifter edge, and at the second exposure, ne

cessary parts are protected and unnecessary parts are exposed and removed in the formed fine patterns.

(0012)

For the purpose of simplification of explanation, following three prior conditions are introduced.

Prior condition 1: fine patterns are all parallel to the x -axis.

Prior condition 2: the distance of centerline of fine patterns 1100 existing adjacently vicinity each other corresponds to a constant value p, or to its integer multiples.

(0013)

Prior condition 3: the line width of fine patterns 1100 is only one type and is equal to that of the pattern formed by the light shading part generated when shifters with width of p are arranged in the interval of p. The patterns in Fig. 22 satisfy these conditions. Now, one of the objects of the present invention is to automatically generate a shifter pattern and a light shading pattern for M1, and a light shading pattern for M2, from given patterns. Accordingly, normal patterns 1200 are separated into patterns 1300 existing in R-area and patterns 1400 existing out of R-area or in S-area, by calculating a phase designation area 1.

(0014)

Let Fig. 22 be given patterns 1000, the areas shown in Fig. 23 and Fig. 24 are considered as phase designation areas for instance. Although omitted in Fig. 22, phase shift films are cyclically existing, which generate a phase difference π in either case as shown in Fig. 26. In both Fig. 23 and 24, the area of upward distance p from the centerline of top fine pattern and the area of downward distance p from the centerline of bottom fine pattern are regarded as R-area 1.

(0015)

Since Fig. 23 regards only the light transmitting part necessary for forming fine patterns 1100 as R-area 1, the R-area has a complex shape according to the fine patterns 1100. On the contrary, Fig. 24 regards R-area 1 as a rectangular are

a, and decides for enabling to cover most wide range area in the boundary necessary for forming the patterns 1100. The rectangular area that is easily calculated is introd uced as R-area 1 here. A concrete procedure to find R-area will be described in emb odiments.

(0016)

If R-area is found, it is easy to separate given patterns 1000 into pa tterns 1300 existing in R-area and patterns 1400 existing in S-area. As the result, a f irst mask M1 is constructed in a flat structure as shown in Fig. 26, to form patterns including the fine patterns (only fine patterns are shown in Fig. 26) in R-area 1, and S-area 3 shades a light to protect. In Fig. 26, the areas where dots are spread are s hifters 1500, fine patterns 1100 are formed at the edges thereof. The area 1700 cover ed with left downward oblique lines is a light shading part. On the other hand, in a second mask M2, normal patterns of R-area 3 are formed as shown in Fig. 27, R-are a 1 shades a light to protect as well as removes unnecessary patterns formed at M1 by exposure. The area covered with right downward oblique lines is light shading pa rt.

(0017)

As mentioned above, the introduction of R-area 1 enables to separat e areas forming fine patterns and other areas, to form patterns in each area independ ently, and to automatically generate patterns in each area including the shifter from g iven patterns 1100. Although those of Figs. 26 and 27 having defects as they are, th e introduction of R-area 1 greatly performs their duties for automatically generating patterns also in improved methods described hereafter.

(0018)

Another object of the present invention is to enable to imprint patter ns as faithful as possible, even if relative positioning shifts exist in a plurality of ma sks. If M1 and M2 shown in Figs. 26 and 27 are imprinted without errors, objective given patterns 1100 may be formed, however, actually there are relative positioning shifts. Namely, RS-boundary 2 of M1 and that of M2 do not overlap. Consequently,

considering that M2 is imprinted in position shift of right upward to M1, an upper e dge and a right edge of R-area 1 of M2 overlap S-area of M1, and shaded at both M1 and M2, to become unexposed to form unnecessary patterns. This shows that ex posure must be performed from both of M1 and M2 for the parts to be exposed in t he vicinity of RS-area 2.

(0019)

In M2 of Fig. 27, all areas except unnecessary latent image parts ar e considered as light shading parts, however, only pattern parts in R-area must be pr otected. Therefore, only the area, in which the pattern part in R-area is enlarged by t he estimated quantity of positioning shift, is considered as a light shading part and o ther parts are considered as light transmitting parts, so that pattern parts are not expo sed even if positioning shift of masks exist. By this, unexposed patterns will not be generated in the part, in which no pattern is existing (e.g. the upper edge of R-area i n Fig. 27), even if positioning shifts are generated.

(0020)

Further, a measure of the present invention will be explained, when a positioning shift of masks occurred in case patterns exist at RS-boundary part 2. Fi rst, it is described when the edge part of fine pattern is at RS-boundary part 2. The enclosed part 51 by a circle in Fig. 24 corresponds to this. In enlarged figures, a lat ent image 10 formed by M1, an overlap with a part protected by M2 and a resulting pattern 15 are shown in Fig. 28 (a) in case of no mask positioning shift, and are sh own in Fig. 28(b) in case of a shift of M2 to the left in Fig. 28(b). In Fig. 28(a), in which a positioning shift does not exist, an expected pattern is formed, however, in Fig. 28(b), in which a positioning shift exists, the edge of obtained fine pattern beco mes expanded. To solve this phenomenon, as shown in Fig. 25, the area expanded b y α in both sides of axial directions from the interval wherein fine patterns exist is c onsidered as R-area 1. In addition, the protection pattern 2500 by M2 to the fine pat tern is not fatten in the axial direction, though it is fatten in the width direction of t he fine pattern 1100 considering a positioning shift. Figures obtained this process are

shown in Fig. 29. Fig. 29(a) shows the relation of positions between the fine pattern 1100 to be formed and RS-boundary 2, and Figs. 29(b), (c) show the overlap of the latent image 10 formed by M1 and protection part 12 by M2 and resulting pattern 15, in cases a positioning shift exists and does not exist. In spite of the existence of positioning shift, a faithful pattern is imprinted. In the formation of a fine pattern, by expanding R-area 1 by α in the both sides of axial directions, a pattern deformation is not generated and it is possible to decide the position in y axis direction by M1 and x axis direction by M2, even if mask positioning shift occurs.

(0021)

Then, it will be described in the case of Fig. 30(a), wherein a normal pattern 1200 exists at RS-boundary part by expanding R-area by αin the axial direction. First, it will be described what kind of deformation a pattern receives in conventional case no measure is so far coped with positioning shift. Fig. 30(b), (c) show patterns of M1 and M2, respectively. In M2, a normal pattern is uniformly enlarged by fattening. As described above, this is to protect a latent image formed by M1 although a mask-positioning shift exists. If an imprinting is performed without a positioning shift error, a pattern in Fig. 30(a) may be obtained, however, if M2 is imprinted in shifted in the left downward direction as shown in Fig. 30(d), the formed pattern 15 disturbs other adjacent patterns because the fattened part in R-area 1 permeates into S-area 3 and causing a projection.

(0022)

The present invention, for avoiding these problems, provides such the processing to the normal patterns in R-area as fattens by δ only in the width direction (y direction) by M1 and fattens by δ only in the axial direction (x direction) by M2. The patterns of M1 and M2, in which the present invention applied to the pattern of Fig. 30(a), are shown in Figs. 31(a) and (b). The cases, in which M1 and M2 are imprinted without a positioning error, M2 is shifted right upward, and M2 is shifted left downward, are shown in Figs. 31(c), (d), and (e), respectively. Either of formed pattern shapes does not generate any constriction or projection, and almost fai

thfully reflects the design pattern. This is caused by separate fattening of the normal patterns in R-area in the directions of upward and downward by M1 and in the directions of leftward and rightward by M2, therefore only the left and right edges (only right edge in the example of Fig. 30) of normal patterns in the area are defined by M1 and the rest edges are defined by M2, regardless of the inside or outside of the area, even if a positioning shift occurs.

(0023)

[Effects of the Invention]

In a pattern forming for forming one layer by exposure using a mask including a pattern, which shifts a phase difference of light passing both sides of a fine pattern to be formed to approximately π, and by a plurality times of exposure including exposure for eliminating unnecessary patterns caused thereby, an area commonly shaded exposure by a plurality of masks remains as a pattern. A phase shifter divides an exposure area into an area with a necessary fine pattern and an area without a fine pattern; thereby one mask provides a shifter, and comprises a mask shifter pattern having an edge corresponding to the fine pattern in the area having the fine pattern, and a mask pattern corresponding to other patterns, and makes the area which does not have the fine pattern a mask pattern for shading; the other mask does not provide a shifter, but comprise a normal mask pattern for forming patterns existing in the area without providing a shifter and a mask pattern for removing unnecessary pattern in the pattern belonging to the area to form a shifter, as a result a shifter pattern and a mask pattern in the two masks can be easily automatically produced. Further, the formed pattern is a part that together shaded by the two masks, therefore may greatly reduce the effect to the pattern causing by a positioning shift and may increase allowance for positioning, by fattening a mask pattern in the axial direction in one mask and fattening the other mask in the direction orthogonal to this axis in the other mask.

(0024)

[Embodiment]

It will be described a case that the present invention is applied to a gate layer in a LSI, in which a fine pattern formation is required. The process flow of an embodiment is shown in Fig. 1, and given input pattern data for making a mas k by using the present invention are shown in Fig. 2-Fig. 6. Fig. 2 is input pattern d ata 1000 including the fine pattern, and is regarded to satisfy three prior conditions d escribed in "Means to solve the problems". Fig. 3 and Fig. 4 show two masks M1 a nd M2, by which a pattern of Fig. 2 is formed. M1 includes a shifter, but M2 does not include a shifter. As described above, as a normal pattern generates a pattern sep arating an R-area and an S-area, three types of pattern data, i.e. pattern data 1500 fo r the shifter, pattern data 1600 for the R-area, and pattern data 1700 for the S-area, are necessary to manufacture an M1 mask. Similarly, three types of pattern data, i.e. pattern data 2500 for protecting the fine pattern formed by the shifter of M1, patter n data 2600 for the R-area, and pattern data 2700 for the S-area, are necessary to m anufacture an M2 mask. These pattern are shown in Fig. 3 and Fig. 4

(0025)

Fig. 1 shows a process flow for making each three types of pattern data for M1, M2, or total six types of pattern data 1500, 1600, 1700, 2500, 2600, and 2700 f rom the input pattern data 1000. Squares with rounded edge show a data processing, and its input and output are pattern data shown by normal squares. The data proces sing requires nine types from 101 to 109, and the contents of processing and its con crete implementation method are described below. Further, the implementation metho d described here is an example, and the method is not limited to this.

(0026)

The data processing described below handles mask data of two-dime nsional graphic data. A contour extraction from the two-dimensional data, a uniform width fattening or thinning which is called a resizing, black and white reversing proc essing in chip area, or a product set operation with plurality of input data or the like

are Design Rule Check (DRC) for the LSI mask pattern data or data processing for a drawing of the mask using an electron beam, and are usually processed already. Therefore, the explanation of concrete processing method is omitted if it is a usually performed processing (refer to for example "Advancing LSI Mask Pattern Data Inspection", pages 90-107, Nikkei Electronics, April 28, 1980).

(0027)

A fine pattern extraction processing 101 separates the given pattern 1000 into a fine pattern 1100 and a normal pattern 1200. If the width d of the fine pattern is known, it may be carried out by the following processing.

(1) By fattening the given pattern 1000 by the distance of d/2,

(2) By extracting the contour,

(3) By fattening the result of (2) by the distance of d/2, then the obtained result is the normal pattern 1200,

(4) By deducting the normal pattern 1200 from the given pattern 1000, then the obtained result is the fine pattern 1100 of width d.

(0028)

By letting Fig. 2 as the pattern 1000 and by thinning it by the distance of d/2 together with the pattern 1000 given in Fig. 7, and in Fig. 8, there are shown normal patterns from 1200-1 to 1200-4, which are obtained by flattening graphics 1010-1 to 1010-4 by the distance d/2, and fine patterns from 1100-1 to 1100-4, which are obtained based on the normal patterns. Usually the line width of fine patterns is known, however, if it is unknown, the above mentioned processing is first performed, by letting the line width as the maximum considerable width, i.e. d of 0.49 microns. The obtained fine patterns 1100 include all patterns, which are less than the width of 0.49 microns. Then the same processing is performed by letting d a little smaller. If this processing is repeated by letting d slightly smaller, fine patterns will be disappear in some moment, to become a zero set. The last d just before the zero set corresponds to the width of fine patterns.

(0029)

A centerline extraction processing is a processing for carrying out th e central line segment 1250 of the fine patterns. From the prior conditions the line w idth of fine patterns is one type, and the line width is known by the fine pattern extr action processing, therefore the processing is easy. The relation between the fine patt erns from 1100-1 to 1100-3 and the center line segments from 1250-1 to 1250-4 is s hown in Fig. 9.

(0030)

R and S-area decision processing is a processing to decide an R-are a 1 and an S-area 3 based on the central line segment 1250 of the fine patterns data. Let centerline segment data be n pieces in all, and let the distance between adjacent centerline segment data is known. In case of unknown, it may be known by analyzi ng the data.

(1) Making rectangles with the width of 2L by fattening both sides by the distance o f L across the centerline segment 1250,

(2) performing the contour extraction processing based on the n pieces of rectangles, numbering the polygons formed by connecting the rectangles, and providing the pol ygon number to each rectangle constituting the polygon,

(3) sorting the n pieces of rectangle data by the polygon number, fetching the rectan gles forming the same polygons, to carry out the minimum rectangle area that can c over the polygon area,

(4) widening the rectangle area obtained in (3) α-by-α in both axial directions to let it new rectangle areas, and if the new areas overlap or come in contact each other, p roviding to those the same polygon number, to return (3),

(5) thinning the width direction of rectangle area obtained in (4) L-by-L in both side s, then fattening it p-by-p, and obtained area is R-area 1.

(6) And the S-area 3 may be carried out by deducting the R-area 1 obtained in (5) f rom the pattern forming area.

(0031)

A processing for carrying out the R-area by collecting the centerline

segments adjacently existing each other. The explanation of the processing of the pr esent embodiment is shown in Figs. 10 and 11. Letting each of centerline segments f rom 1250-1 to 1250-4 a rectangle with the width of 2L, all are connected to become one polygon. Since no other polygons exist, the R-area in Fig. 11 may be carried o ut by the above processing (3), (4), and (5). If the distance of adjacent centerline seg ment data is less than 2L, the two rectangles are connected to form one polygon. Th erefore, if 2p □2L □3p and the distance of adjacent centerline segment data is belo w 2p, it becomes one R-area as shown in Fig. 10, and if the distance is 3p, it may be considered another R-area.

(0032)

A normal pattern extraction-processing 104 within the R-area and a normal pattern extraction processing 105 within the S-area.

In the normal pattern extraction processing 104 within the R-area, th e normal pattern data may easily be carried out by the product set operation of the R-area data obtained in the R-area decision processing 103 and the normal pattern da ta. The normal pattern extraction processing within the S-area is same. The normal p attern from 1300-1 to 1300-4 within the R-area and the normal pattern from 1400-1 to 1400-2 are shown in Fig. 12.

(0033)

A width direction fattening processing 106 fattens the normal pattern 1300 within the R-area by δ in both sides in the width direction. The result is show n in Fig. 13. The normal patterns from 1300-1 to 1300-4 within the R-area become R-area patterns from 1600-1 to 1600-4 for M1. The quantity δ is determined by the relative joining accuracy, e.g. a value of 0.2 micron is considered.

(0034)

An axial direction fattening processing 107 fattens the normal patter n 1300 within the R-area by δ in the axial direction in the R-area. The result is sho wn in Fig. 14. The normal patterns from 1300-1 to 1300-4 within the R-area become R-area patterns from 2600-1 to 2600-4 for M2. S-area patterns from 2700-1 to 270

0-2 for M2 are together shown in Fig. 14. The quantity δ is the same value because the fattening processing is same as that of the width direction.

(0035)

A shifter pattern generating processing 108 generates a pattern for the shifter by inputting the R-area data and its corresponding data for the centerline. The area with or without shifter may be assigned by fetching centerline segment data 1250 sequentially, while sorting the centerline segment data 1250 in the width direction (for instance, from upward to downward in the y direction in Fig. 15) for each area. Fig. 15 shows the assigned result.

A fine pattern protection processing 109 produces a fine pattern protection pattern 2500 for M2, by fattening the centerline segment data 1250 by ε in the width direction. An embodiment is shown in Fig. 16. The symbol ε may be same as δ in quantity, which is used in the width direction fattening processing 106 and is considered a joining between masks, however, ε may be greater than δ, for instance the value of 0.3 microns is used for the meaning of enhancing the dimensional accuracy by completely shading the fine pattern that becomes a gate electrode.

(0036)

By performing nine types of calculation processing mentioned above, M1 and M2 patterns may be automatically generated. As shown in Fig. 3, M1 is composed by using shifter patterns 1500-1 and 1500-2, a protection pattern in the S-area 1700, and normal patterns from 1600-1 to 1600-4 in the R-area. As shown in Fig. 4, M2 is composed by using fine protection patterns from 2500-1 to 2500-4, R-area patterns from 2600-1 to 2600-4, and S-area patterns from 2700-1 to 2700-4.

(0037)

An example is shown in Fig. 5, in which two masks are overlapped without error. If a positive type resist is used, in which the part disposed by light is dissolved by exposure, a pattern is generated by that the meeting part of a latent image area 10 and a protected area 12 of the shaded part of M2 is not exposed. It is known that the pattern of Fig. 2 is formed. Fig. 6 shows the case where M2 is imprin

ted left downward shifted to M1. There is no fatal defect in the pattern shape, although the relative position between the fine pattern and the normal pattern is shifted. In the gate pattern, there is a problem in overlapping accuracy with other layers, for instance with a contact hole layer, however, in this point, there is no significant difference between the normal method and the method of present invention.

(0038)

Now, there is provided a supplementary explanation about three constraints, which are described in " Means for Solving the Problems" on condition of the gate layer pattern, using the standard cell design method. The prior condition 1, in which all of the fine patterns are parallel to the x-axis, may be parallel to the y-axis, or further all of the fine patterns included in that area may be parallel to the x or y-axis, when there is a plurality of first areas, in which the phase is designated.

(0039)

The condition 2, in which the distance between the centerline part of the fine patterns is p or a multiple of p, is considered to satisfy in the standard cell method. The third condition to the line width of fine patterns has no constraint against the line width, if the shifter edge method described in Fig. 18 is applied. Further, the type of line width needs not to be limited to one type, if considering that the pattern width becomes a plurality of types in the fine pattern extraction processing 101, the decision of light shading body width and the fine pattern protection processing 109 in M2, which is necessary for its fine pattern shape required for e.g. the shifter edge part. Actually, the gate pattern of CMOS causes a difference in gate pattern width between the p-type transistor and the n-type transistor, however, it is easy to deal with as mentioned above.

(0040)

Therefore, this method of the present invention may be applied for forming a gate layer pattern using the standard cell design method and also forming patterns, in which fine patterns are arranged at regular intervals.

(0041)

[Effects]

The present invention is composed as described above, therefore has following effects. This method enables to independently form patterns in each area and to automatically generate patterns in each area, including the shifter from given patterns to be formed, by dividing the light exposure area into an area with the fine pattern and an area without the fine pattern, and by separating an area forming the fi ne pattern and an area not forming the fine pattern.

(0042)

Further, the phase shifter fattens normal patterns in necessary areas i n the upward and downward directions in the mask M1, and fattens separately in the left and right directions in the mask M2, therefore, the effect of a position shift ma y be reduced, such that the design pattern is faithfully imprinted without any constric tion or projection of the formed pattern shape, even when M2 is imprinted to M1 wi th a positioning shift.

[Brief Descriptions of Drawings]

Fig. 1 is a processing flow to automatically generate patterns for ph ase shift masks, including phase shift film patterns from given mask patterns;

Fig. 2 shows patterns to be formed;

Fig. 3 is a flattened placement view of a first mask for forming the patterns in Fig. 2 in the implementation of the present invention;

Fig. 4 is a flattened placement view of a second mask for forming t he patterns in Fig. 2 in the implementation of the present invention;

Fig. 5 is an explanatory drawing for patterns, in which two masks o f Fig. 3 and Fig. 4 are imprinted in overlapped without a position shift;

Fig. 6 is an explanatory drawing for patterns, in which the mask in Fig. 4 is imprinted in shifted to the mask in Fig. 3 in the left and right directions;

Fig. 7 is an explanatory drawing for a fine pattern extraction proces

sing 101;

Fig. 8 is an explanatory drawing for a fine pattern extraction processing 101;

Fig. 9 is an cxplanatory drawing for a finc pattern centerline segment extraction processing 102;

Fig. 10 is an R and S-area decision processing 103;

Fig. 11 is an R and S-area decision processing 103;

Fig. 12 is an explanatory drawing for an image extraction processing 104 in the R-area and an image extraction processing 105 in the R-area;

Fig. 13 is an explanatory drawing for a width direction fattening processing 106 to normal patterns in the R-area;

Fig. 14 is an explanatory drawing for a width direction fattening processing 106 to normal patterns in the R-area;

Fig. 15 is an explanatory drawing for a shifter pattern generating processing 108;

Fig. 16 is an explanatory drawing for a fine pattern protection processing;

Fig. 17 is an explanatory drawing for a phase shift method using thc edgc of a phasc shift film;

(a) A cross-sectional view of a phase shift mask,

(b) Complex amplitude of the light transmitted the mask of (a),

(c) A strength distribution of the light transmitted the mask of (a),

(d) A cross-sectional view of a phase shift film for forming fine patterns at p cycle using the edge of a phase shift film;

Fig. 18 is an explanatory drawing for a control method in forming fine patterns using the edge of a phase shift film,

(a) a cross-sectional view of a mask, in which a light shading body is installed, and

(b) a plan view of the mask, in which the edge of the phase shift film is folded in a fine cycle shape;

Fig. 19 shows an example of forming unnecessary patterns when the phase shift film is used;

Fig. 20 is an explanatory drawing of a method for removing the unnecessary patterns shown in Fig. 19 using two masks;

Fig. 21 is an explanatory drawing of an adverse effect on formed patterns when the two masks are shifted in positioning;

Fig. 22 shows patterns to be formed at the time of deciding an R-area in a explanation to expand the area by a distance of α in the axial direction of fine patterns to respond to the positioning shift in masks;

Fig. 23 is an example of an R-area forming at the time of deciding an R-area in a explanation to expand the area by a distance of α in the axial direction of fine patterns to respond to the positioning shift in masks;

Fig. 24 is an example, in which an R-area is formed in rectangular shape at the time of deciding an R-area in a explanation to expand the area by a distance of α in the axial direction of fine patterns to respond to the positioning shift in masks;

Fig. 25 is an example of R-area at the time of deciding an R-area in a explanation to expand the area by a distance of α in the axial direction of fine patterns to respond to the positioning shift in masks;

Fig. 26 is an example of mask patterns of masks with shifters in case the positioning shift is not responded;

Fig. 27 is an example of mask patterns of masks without shifters in case the positioning shift is not responded;

Fig. 28 is a pattern-forming example, in which a positioning shift exists in masks when the masks in Fig. 27 and Fig. 28 are used;

Fig. 29 is a pattern-forming example, in which a positioning shift exists in masks in expanding the area by a distance of α in the axial direction of fine patterns at the time of deciding an R-area;

Fig. 30 is an explanatory drawing, in which a positioning shift is ge

nerated in case the positioning shift is not responded enough,

(a) a pattern to be formed, (b) a plan view of Mask 1, (c) a plan view of Mask, (d) a forming pattern with a positioning shift; and

Fig. 31 is an explanatory drawing, in which a positioning shift in masks is responded by the present invention,

(a) a plan view of patterns of Mask 1,

(b) a plan view of patterns of Mask 2,

(c) a forming pattern with out a positioning shift,

(d) a forming pattern, in which M2 is imprinted shifted upward right to M1,

(e) a forming pattern, in which M2 is imprinted shifted downward left to M1.

(Translation of words in the drawing)

Fig.1

1000. Given pattern data

101. Fine pattern extraction processing

1100. Fine pattern data

102. Centerline extraction processing

1250. Centerline segment data

103. R, S-area decision processing

R-area data

S-area data

1200. Normal pattern data

109. Fine pattern protection processing

2500. Fine pattern protection pattern data for M2

108. Shifter pattern generation processing

1500. Shifter pattern data for M1

1700. S-area protection pattern data

104. Normal pattern extraction processing in R-area

1300. Normal pattern data in R-area

107. Axial direction fattening processing

2600. R-area pattern data in R-area

106. Width direction fattening processing

1600. R-area pattern data for M2

105. Normal pattern extraction processing in S-area

1400. Normal pattern data in S-area

Fig. 2

4. Pattern forming area

1000. Input pattern

Fig. 3

1700. S-area protection pattern

Fig. 4

2. RS boundary

Fig. 5

10. Latent image formed by M1

12. Area protected by light shading part of M2

Fig. 6

10. Latent image formed by M1

12. Area protected by light shading part of M2

Fig. 8

1100-1. Fine pattern

1200-1. Normal pattern

1100-2. Fine pattern

1200-2. Normal pattern

1100-3. Fine pattern

1200-3. Normal pattern

1100-4. Fine pattern

1200-4. Normal pattern

Fig. 9

1100-1. Fine pattern

1250-1. Centerline segment

1250-2. Centerline segment

1100-2. Fine pattern

1250-3. Centerline segment

1100-3. Fine pattern

1100-4. Fine pattern

1250-4. Centerline segment

Fig. 11

1. R-area
2. RS-boundary
3. S-area
4. Pattern forming area

Fig. 12

1. R-area
2. RS-boundary
3. S-area

Fig. 13

1. R-area
2. RS-boundary
3. S-area

Fig. 14

1. R-area
2. RS-boundary
3. S-area

Fig. 15

1. R-area
2. RS-boundary

3. S-area

1500-1. Shifter pattern for M1

1500-2. Shifter pattern for M2

Fig. 16

2500-1. Fine pattern protection pattern for M2

2500-2. Fine pattern protection pattern for M2

2500-3. Fine pattern protection pattern for M2

2500-4. Fine pattern protection pattern for M2

Fig. 17

60. Mask illumination light

61. Mask substrate

1500. Phase shift film

Fig. 18

60. Mask illumination light

61. Mask substrate

62. Light shading body

1500. Phase shift film

Fig. 19

1100. Fine pattern to be formed1500. Phase shift pattern

15. Formed pattern

Fig. 20

1500. Phase shift pattern

13. Light shading part

14. Light transmitting part

15. Formed pattern

Fig. 21

8. Pattern to be formed

13. Light shading part

1500. Phase shift pattern

10. Latent image formed by M1

14. Light transmitting part

Fig. 22

1100. Fine pattern

1200. Normal pattern

4. Pattern forming area

Width direction

Axial direction

Fig. 23

1200. Normal pattern

1100. Fine pattern

1. R-area

2. RS-boundary

3. S-area

4. Pattern forming area

Fig. 24

1200. Normal pattern

1100. Fine pattern

1. R-area

2. RS-boundary

3. S-area

4. Pattern forming area

Fig. 25

1. R-area

2. RS-boundary

3. S-area

4. Pattern forming area

Fig. 26

1500. Shifter pattern

1700. S-area protection pattern for M1

1. R-area

2. RS-boundary

3. S-area

4. Pattern forming area

Fig. 27

1. R-arca

2. RS-boundary

3. S-area

4. Pattern forming area

2900. Light shading part for M2

Fig. 28

How masks overlap

Forming pattern

1. R-area

2. RS-boundary

3. S-area

10. Latent image formed by M1

12. Area protected by light shading part of M2

15. Formed pattern

Fig. 29

How masks overlap

Forming pattern

1. R-area

2. RS-boundary

3. S-area

10. Latent image formed by M1

12. Area protected by light shading part of M2

15. Formed pattern

1100. Fine pattern to be formed

Fig. 30

1. R-area

2. RS-boundary

3. S-area

1200-6. Normal pattern

Fig. 31

1. R-area

2. RS-boundary

3. S-area

1200-6. Normal pattern (Pattern to be formed)

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